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MAXIMUM OXYGEN UPTAKE AS A CRITERION OF HUMAN RESISTANCE TO HYPOXIA, HYPERTHERMIA AND HYPOTHERMIA

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[Article by A. M. Vasilenko, submitted 5 Nov 79]

[English abstract from source]

Study of experimental results shows that physical work capacity is an adequate indicator of human tolerance to adverse environmental effects. Maximum oxygen uptake, being a measure of physical work capacity, can be used as a prognostic indicator of human tolerance and adaptive capability in a hypoxic, high or low ambient temperature environment. Increase in maximum oxygen uptake under the influence of training or adaptation to hypoxia is accompanied by increase in heat and cold resistance.

[Text] The question of cross-resistance of the body has been the subject of scientific debate for many years. Cross-resistance is generally construed as the body's ability to withstand the effects of a broad spectrum of deleterious environmental and endogenous factors by maintaining normal functions of different systems and preserving the dynamic regulatory correlations between them [1].

When exploring space and underwater areas, man is subject to the effects of diverse deleterious factors, the most widespread ones being hypoxia, high and low ambient temperatures.

The objective of this survey was to analyze the current literature dealing with evaluation of man's cross resistance to these environmental factors on the basis of an integral criterion, maximum oxygen uptake (MOU).

According to conceptions being developed in recent years, human efficiency [fitness for work] can serve as a criterion of the body's resistance to deleterious factors [1, 2], and MOU is the main indicator thereof, according to the recommendations of the International Biological Program [3]. The same indicator serves as a gage of so-called physical fitness, which is widely used in screening and dynamic monitoring of the health status of some occupational groups that are subject to a set of deleterious factors in the course of their professional work [4-6]. The MOU, which reflects primarily the functional state of the cardiac, respiratory and locomotor systems, depends on sex, age, conditioning and several other parameters that characterize the individual. The habitat has a strong influence on magnitude of MOU.

A comparative analysis of MOU in representatives of different occupational groups engaged in moderate and heavy physical labor and living in the lowlands and foothills (up to 1000 m above sea level) revealed that the miners in the foothills have reliably lower MOU and MOU per kg body weight, as compared to workers in the machine building industry in the northern part of the central zone of the USSR. For these groups, the mean values of these parameters constituted 2.8 and 3.2 liters/min, 39.6 and 45.7 $ml \cdot min^{-1} kg^{-1}$. Additional differential analysis of the results revealed that the demonstrated difference between MOU levels is attributable primarily to differences between groups of workers engaged in moderate physical labor. However, the differences between groups performing heavy labor were not significant [7].

The obtained results confirm the known data to the effect that even mild hypoxia lowers MOU and that a constant and intensive physical load (PL) diminishes the influence of this factor.

Different results were obtained from a study of two groups of young men residing in the foothills (760 m above seal level) and in the mountains (3200 m above sea level). As in the preceding study, MOU was measured in the subject's customary habitat. Maximum PL at high altitude constituted 1280 kg-m/min and at low altitude it was 1100 kg-m/min. The same submaximum MOU ($\dot{V}O_2$) was reached by the mountain dwellers with less increase in functional tension of the cardiovascular system than for the foothill dwellers, against the background of greater tension of the respiratory system [8].

According to other data, the ventilatory reaction to acute hypoxia, both at rest and during PL, is markedly diminished. Vital lung capacity of infants up to 1 year old born in the lowlands and highlands was about the same. At 9-13 years of age this parameter was 21% higher among highland children than their peers living in the lowlands, and by the age of 18-20 years the difference was up to 45%. A decrease in pulmonary ventilation under the influence of acute hypoxia, as well as increase in lung volumes, are observed under the influence of the environment, and they are not genetically determined or the consequence of adaptation in the prenatal period [9].

The results were just the opposite in another comparative study of mountain and lowland dwellers. In children born in the mountains, there was increased muscularization of pulmonary arterioles, which led to an increase in vascular resistance and pulmonary hypertension. As a consequence of these changes, there was an increase in diffusion capacity of the lungs and dilatation of the right cardiac ventricle. Development of these adaptive reactions begins in the prenatal period, as indicated by the significantly lower birth weight and higher ratio of weight of placenta to weight of the neonate at high altitudes. Short mountain dwellers (<160 cm) presented reliably higher MOU per kg body weight, as compared to representatives whose average height was over 162 cm [10]. In view of the fact that height is primarily a genetically determined factor [11], it may be assumed that adaptation to hypoxia not only develops in the prenatal period, but is a genetically determined feature of the organism, to a significant extent. At the same time, MOU and vital lung capacity reach levels that are typical of mountain dwellers in individuals born in the lowlands and who moved to the mountains in childhood or youth. The rate of adaptation of these parameters is inversely proportional to the age at which the move was made and proportional to time spent in the mountains.

In spite of the fact that there are differences of opinion concerning the dominant role of heredity or environment, the existing data indicate that the development of reactions that implement hypoxic resistance is associated with an increase in MOU. Just like chronic exposure to a hypoxic environment leads to an increase in MOU, so an increase in MOU as a result of conditioning is associated with an increase in resistance to hypoxia. It is known that MOU/kg body weight drops by an average of 3.2% per 300 m at high altitudes (over 1500 m above sea level)[4, 10]. However, it must be noted that the degree of decline depends on the base value of this parameter. For example, in athletes who trained for endurance and had high MOU, fitness was less affected when they moved to a high altitude than in unconditioned individuals. The knowhow gained to date in sports physiology demonstrates convincingly that the combination of physical exercise and exposure to hypoxia is effective in rapidly increasing fitness, which is accompanied by a marked increase in MOU. As a result of exercising at altitudes of 1000 and 3000 m, with the same intensity of training loads, the higher the altitude, the more marked the increase in MOU [12]. The same direction of effects of intensive PL and adaptation to hypoxia resulted in acquisition of higher resistance to accumulation of lactate and, consequently, to increased efficiency in a hypoxic environment [8, 12].

The results of a study of thresholds of ventilation reactions of subjects to hypoxic and hypercapnic stimuli failed to demonstrate a relation thereof to sex, age and MOU [13]. However, this cannot be indicative of independence of hypoxic resistance from MOU, since there is still no convincing evidence of a link between level of threshold of ventilation reaction to hypoxia and resistance to hypoxia [14].

High vital capacity and diffusion capacity of the lungs, increased overall volume of circulating blood, oxygen and buffer capacity thereof, increased permeability of capillaries and desaturation capacity of tissues, the activity of a number of enzymes and more adequate regulation of circulation and respiration are all involved in increasing resistance to hypoxia in individuals with high MOU [2, 12, 15, 16]. However, in spite of the seemingly clear mechanism of increased resistance to hypoxia with increase in MOU, some studies failed to confirm this link [17]. Thus, the question of relationship between MOU and resistance to hypoxia requires further investigation. There is a more unanimous opinion concerning the same direction of effects of conditioning and heat adaptation on resistance to hyperthermia. Physical fitness is most intimately related to body and ambient temperature. The circadian rhythm of body temperature are related to variations in athletic achievements [18, 19], pulmonary ventilation and VO_2 with PL [20, 21]. Submaximum PL performed at 0700 h (period of low values in the cycle of circadian body temperature) is associated with less marked heat-regulating tension than the same PL performed at 1600 h [22].

For the time being there is no agreement as to changes in MOU as a function of time of day. According to some authors [23, 24], MOU diminishes reliably at night, whereas other authors find no differences in MOU as related to time of day [25, 26]. The inconsistency of these findings could be attributed to methodological differences in determining MOU. An indirect measurement, according to heart rate with a submaximal load, using the Astrand nomogram, failed to demonstrate differences in this parameter in the course of the day, whereas direct testing showed a reliable 5% decline of MOU at night [23].

In view of the results of numerous studies, it can now be considered proven that individuals who are not adpated to heat but with high MOU present greater heat resistance than individuals with low MOU [27-29]. The efficacy of training as a means of increasing heat resistance is proportionate to the intensity of conditioning PL [30, 31]. It is known that there is a negative correlation between rate of elevation of body temperature with exposure to heat and resistance of PL and MOU [28, 30, 32]. There are indications that acclimatization to heat leads to an increase in MOU, even without being combined with physical training [33]. The highly reliable correlation between resistance to heat and magnitude of MOU makes it possible to use the latter as a criterion of human endurance of heat. It is believed that individuals whose MOU exceeds 40 $m\ell \cdot min^{-1} \cdot kg^{-1}$ have high heat resistance, whereas with MOU below this level man cannot be considered resistant to high temperatures [34].

The increased heat resistance of individuals with high MOU is attributable primarily to the fact that heat production with a PL is not proportionate to the absolute $\dot{V}O_2$ but to the $\dot{V}O_2$/MOU ratio [35]. This fact, which is of basic importance to comprehension of the mechanisms involved in heat resistance, was distinctly demonstrated in a number of studies conducted at different ambient temperatures and intensities of PL [35]. Graphs were plotted on the basis of the results of studies of resistance to high temperatures among nonacclimated, partially and completely acclimated individuals, and they make it possible to predict body temperature with a given value of $\dot{V}O_2$/MOU. Thus, with a psychrometer reading of 32.2°C, rectal temperature will reach 38.3°C in 4 h of work at $\dot{V}O_2$/MOU = 35%. With $\dot{V}O_2$/MOU = 48%, body temperature will rise to 39.7°C within the same period of time. Body temperature at ambient temperature of 34°C can remain stable when working with $\dot{V}O_2$ not exceeding 30% MOU, and at 29°C ambient temperature when it does not exceed 43% MOU. When ambient temperature is below 29°C, the body temperature can remain stable with a PL when $\dot{V}O_2$ reaches 50% MOU [32].

These data cannot be considered accurate enough, since they are based on MOU values measured prior to exposure to heat, while MOU diminishes appreciably in the presence of heat stress. In studies conducted with the subjects submerged in water varying in temperature, it was demonstrated that MOU reaches maximum values with water temperatures of 30-35°C. A 10% increment of MOU for every degree of elevation of water temperature is observed in the temperature range of 20-30°C. MOU drops drastically in water above 35°C [36]. In the presence of thermal stress, $\dot{V}O_2$ decreases with both submaximum and maximum PL. Differential evaluation of aerobic and anaerobic fractions of metabolism with submaximal PL revealed that they constituted 74 and 26%, respectively, under comfortable conditions, whereas the aerobic fraction dropped to 65% and the anaerobic rose to 35% in a hot microclimate [37]. As a result of 12-day conditioning, which led to an increase in MOU on the average from 2.6 to 3.2 /min, there is a decline not only of relative (due to increase in MOU) but absolute $\dot{V}O_2$ with the same intensities of PL. Concurrently there is a decrease in heat production, rectal and skin temperature, with increase in perspiration [38].

In individuals with igh MOU, along with diminished heat production and intensified secretory activity of sweat glands leading to slower elevation of body temperature, there is a decline of temperature threshold of perspiration [39-42]. Improvement of the mechanism of evaporative heat loss is manifested by a change in composition of sweat and faster achievement of constant rate of perspiration [43, 44].

increased secretory function of the sweat glands is fraught with the possibility of development of dehydration disorders, which are often the immediate cause of thermal injuries. However, along with increased capacity for loss of fluids, the conditioned (with high MOU) body also has greater reserves of endogenous fluid. One of the important distinctions of the conditioned organism is the capacity for rapid enlistment of free fatty acids, which leads to elevation of anerobic threshold and oxidation of predominantly fats. Oxidation of lipids is associated with twice as much fluid production that oxidation of carbohydrates; for this reason, with submaximum PL in the presence of heat stress, the individual with high MOU has a higher potential for perspiration [46].

Performance of physical exercise under febrile conditions leads to serious hemodynamic changes: increased delivery of blood to working muscles and faster blood flow in the skin to eliminate excess heat. The high functional capabilities of the cardiovascular system, which provides for a high MOU, is also the basis for enhancing heat resistance. The increase in total circulating blood volume as a result of systemic effects of heat and physical loads can reach 10%, which is considerably greater than the increasing demands of cutaneous circulation. For this reason, there is also an increase in blood supply to working muscles, diastolic filling of the heart, stroke volume and, as a consequence, an increase in orthostatic stability at high ambient temperatures [46].

In well-conditioned athletes, cutaneous vasoconstriction may dominate over vasodilatation, even in the presence of marked hyperthermia [47-51].

The hemodynamic distinctions acquired as a result of training provide for maintenance of a temperature gradient between the endogenous environment and body surface when there is difficulty in heat transfer. When working in protective gear, the difference between rectal temperature and mean weighted skin temperature decreased by 0.45°C in 56 min, when their mean MOU constituted 45 $ml \cdot min^{-1} \cdot kg^{-1}$ (the mean duration of working until they had to stop), whereas in subjects with MOU = 36 $ml \cdot min^{-1} \cdot kg^{-1}$ it diminished by 1.2°C in 35 min [52]. A higher temperature gradient between the endogenous environment and body surface, which increases convective heat transfer, is an important factor in providing heat resistance, and it serves as a reliable prognostic indicator when evaluating the thermal status of the organism when there are limited possibilities for evaporative heat loss [53, 54].

Recently, yet another mechanism was discovered, which provides for better heat resistance among conditioned or heat-adapted individuals. It was demonstrated that thermoregulatory disturbances at high ambient temperatures are closely related to an increase in osmotic pressure in plasma, as a result of dehydration [55]. Since cutaneous and muscular vasodilation occurs faster and is more marked in conditioned individuals under the concurrent effect of PL and high temperature, the drastic pressure drop in capillaries leads to passage into the capillaries of interstitial fluid, which is less tonic than plasma, and this leads to a drop of osmotic pressure of the latter and, consequently, prevents development of thermoregulatory disturbances [56].

The body's adaptation to circulatory hypoxia and work-related hyperthermia, which appear while performing intensive exercise, is apparently the basis for increasing its resistance to hypoxic hypoxia and thermal stress caused by exogenous temperature conditions.

Conditioning, which leads to very high MOU (marathon running) is associated with an increase in cold resistance, along with increase in heat resistance. Marathon runners present less marked cold shivering under the influence of low temperatures. In addition to the well-known factor of decline of perspiration threshold under the influence of high temperatures, this made it possible to expound the hypothesis that the thermoregulatory reference point is shifted down in marathon runners [57].

The data referable to the possibility of development of cross-resistance to cold and heat were confirmed in a comparative study of physiological reactions of marathon runners and swimmers, whose mean MOU constituted 66.5 a[illegible] $m\ell \cdot min^{-1} \cdot kg^{-1}$, respectively. When submerged in a tub with 30°C temperat[illegible], $\dot{V}O_2$ of swimmers increased linearly with immersion time over a period of 90 min, [illegible] stabilized at a level exceeding the base level by 60%. In marathon runners, $\dot{V}O_2$ increased for the first 30 min and became stable in the 30th-60th min of immersion. Rectal temperature of the swimmers was substantially lower than that of the marathon runners before and during the 1st h of immersion [57].

Thus, in spite of the absence of specific adaptation to cold, the marathon runners presented the same cold resistance as swimmers, who constantly encountered this factor. Maximum insolation was 20% higher than previously recorded indices of unconditioned individuals [58]. The high cold resistance of marathon workers was unrelated to the distinctions of fatty insulation or metabolic heat production; rather, it was due to the increased capacity for peripheral vasoconstriction, which developed with prolonged performance of heavy physical labor.

Studies were recently conducted, the results of which revealed that an increase in cold resistance can be observed not only in skilled athletes, but unconditioned individuals under the influence of 40-day training [59].

The results of studies dealing with cross-resistance to hypoxia and cold are sparse and contradictory. There are indications of a negative correlation between resistance to hypoxia and cold [60]; on the other hand, it was demonstrated that intermittent cold leads to an increase in resistance to hypoxia [61]. Data obtained from a comparative study of cold resistance among mountain and lowland dwellers revealed at least two physiological distinctions in the highlanders that gave them higher cold resistance: higher level of basal metabolism and increased blood flow in the extremities, which caused them to have a higher temperature [62].

Cold-caused peripheral vasodilation, which is observed in high-altitude dwellers in their natural habitat, is also observed in tests made at sea level. The mountain dwellers demonstrated higher cold resistance, manifested by a slower rate of decline of body temperature and skin, and less marked cold shivering when exposed to total-body cold. Under the local influence of cold, the duration of the period of initial vasoconstriction in the fingers was substantially shorter and blood flow reliably faster in the highland dwellers than in lowland residents [63].

The small number of studies does not enable us to gain a clearcut idea about the mechanism of increase in cold resistance with increase in the body's MOU. Regular training, which leads to increase of MOU, is associated with a decrease in heart rate, arterial pressure and VO_2 at rest. The same distinctions, which are indicative of prevalence of parasympathetic influences, are observed in hypoxia-adapted

individuals. These properties could be involved in providing greater functional reserves of the cardiorespiratory system to provide resistance to acute cold factors. Hyperthermic and hypothermic states are associated with development of phasic circulatory hypoxia; for this reason, it may be assumed that an organism with high resistance to hypoxia will also manifest higher resistance in a state of hyperthermia or hypothermia.

In spite of the fact that there are many unclear elements with regard to the mechanisms that provide cross-resistance, the obtained data warrant the conclusion that an increase of MOU is associated with acquisition of functional distinctions which prevent development of hypoxic, hyperthermic and hypothermic states under the influence of the corresponding conditions, on the one hand, and provide for better tolerance of these states, on the other. Moreover, MOU as an indicator of fitness reacts clearly to a change in gas composition and temperature of the environment, so that it can be used as a criterion in setting standards for deleterious factors. Thus, MOU can be used as an integral indicator when assessing the functional state of the body, as well as when predicting endurance thereof under extreme conditions.

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EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

UDC: 629.78:[612.13+612.173.3

STUDY OF HEMODYNAMICS AND PHASE STRUCTURE OF CARDIAC CYCLE IN SECOND CREW OF THE SALYUT-6 ORBITAL STATION AT REST

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 10-14

[Article by A. D. Yegorov, O. G. Itsekhovskiy, I. I. Kas'yan, I. V. Alferova, A. F. Polyakova, V. F. Turchaninova, V. I. Bernadskiy, V. G. Doroshev and Ye. A. Kobzev, submitted 3 Sep 79]

[English abstract from source]

[illegible] blood redistribution and hypervolemia of the upper body. [illegible] blood volume and pulse blood [illegible] These changes varied phasically in the [illegible] up to 140 days did not cause any pathologies in [illegible]

[Text] Studies of the human cardiovascular system in the presence of prolonged weightlessness revealed signs of redistribution of blood in a cranial direction as a result of disappearance of hydrostatic blood pressure and relative deconditioning of mechanisms of regulation of the circulatory system, which is manifested in flight by intensification of the reactions to load tests [1-4]. Prompt detection and prediction of adverse states related to these phenomena are important for correct planning of the work and rest schedule, and determination of efficacy of preventive measures.

Studies pursued with the participation of the crew commander (CPR) and flight engineer (FLE) were a logical continuation of accumulation of scientific data pertaining to the study of the behavioral of the circulatory system during orbital flights.

Methods

Polynome-2M and Rheograph-[illegible]trapolar system) equipment was used to study inflight hemodynamics. We recorded [illegible] electrocardiogram in the DS lead, kinetocardiograms from the region of the apical beat, tachooscillograms with placement of the compression cuff on the arm [shoulder], sphygmograms of the femoral artery, rheograms of the trunk in the shoulder-shoulder lead, rheoencephalograms of both cerebral hemispheres with electrodes on the forehead--mastoid process, rheograms of the forearm and leg in longitudinal leads, with the use of circular electrodes. During the

flight, we analyzed the heart rate (HR), arterial pressure (AP) by the method of N. S. Korotkov [5], phase structure of the cardiac cycle from the kinetocardiogram [6] and velocity of pulse wave propagation in the aorta (VPWa) according to pulse lag in the femoral artery in relation to time of opening of aortic valve, as determined on the kinetocardiogram. From the rheographic curves we determined the stroke (SV) and minute (MV) volumes of circulation [7] and rheographic parameters indirectly reflecting pulsed filling and tonus of vessels of the regions examined [8]. There was no strictly fixed time of day when measurements were made, since they were determined by the distinctions of the 24-h cyclogram and telemetric communication with the ground, but as a rule they were preceded by moderate physical and emotional activity.

Results and Discussion

The results illustrated in Figures 1 and 2 indicate that the dynamics of HR of both cosmonauts presented a tendency toward decline at the early stage, stabilization in the 3d-4th week and progressive increase from the 61st day on, which continued virtually to the end of the flight. The HR increment, as compared to the mean preflight level was in the range of 12-35% for the CDR and 12-27% for the FLE. For the first 2 months the CDR presented a decline of AP parameters followed by a tendency toward recovery. In the FLE an analogous direction of changes was demonstrable in lateral systolic pressure, while the drop of pulsed AP was the most marked on the 7th, 61st, 119th and 137th days (by 22, 34, 37 and 27%, respectively, as compared to the preflight level).

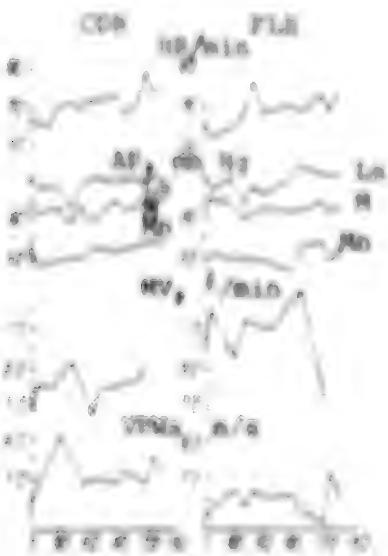

Figure 1.
Dynamics of HR, AP, MV AND VPWa during 140-day flight, at rest
Mn) minimal
M) mean
Ls) lateral systolic

The typical distinction of dynamics of indices of phase structure of the cardiac cycle (systole and diastole of the left ventricle) was that there was persistent shortening of the phase of isometric contraction (IC) and less stable relative extension of the period of ejection by the left ventricle (PE) in both cosmonauts, and in most cases this was indicative of development of a syndrome similar to the well-known volumetric load phase syndrome [9]. There was 12-41% shortening of the IC phase, 5-20% extension of PE in relation to proper time for given HR and 9-30% in relation to mechanical systole. Concurrently thre was 7% increase in intrasystolic index and 16-19% decrease in index of myocardial tension. The changes in diastolic indices of the left ventricle were characterized by a decrease in phase of isometric relaxation by 19-30% and extension of filling period. It should be noted that the changes in systolic indices and isometric relaxation were not clearly related to duration of the flight. Concurrently, the duration of the filling period increased by 19-23% in both cosmonauts during the 1st month of flight, but thereafter did not differ from preflight levels; this increase was noted chiefly with reference to the phase of rapid filling. The changes in phase indices were more marked in the CDR.

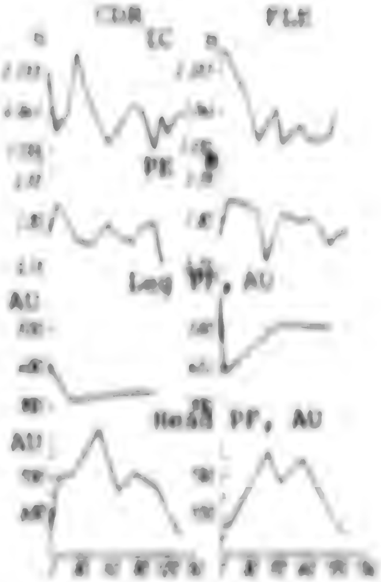

Figure 2.
Dynamics of phase of isometric contraction, ejection period and indices of pulsed filling (PF) of head and leg vessels at rest during 140-day flight; AU--arbitrary units

The dynamics of circulatory blood volumes determined rheographically revealed that SV increased appreciably (by 20-32%) on the 4th-6th days in both crew members. Thereafter, this parameter did not differ from preflight levels, with the exception of the 62d day for the CDR and 119th day for the FLE, when a decline was observed (by 26-28%). MV corresponded to the mean preflight level throughout the flight, or else was higher, but without exceeding the range of maximum levels on the ground. In most cases, we observed a 2-54% in VPWa in both cosmonauts.

Rheographic examination of regional hemodynamics revealed that there was redistribution of pulsed filling of vessels between the upper and lower parts of the body. Pulsed filling of head vessels increased the most on the 50th-85th flight days (by 79-101%), then reverted to the base level or even decreased. Pulsed filling of arm vessels increased or did not change, while filling of leg vessels was decreased, as compared to preflight levels (by 15-36%), throughout the flight. The dynamics of arteriolar and venous tonus of the regions examined were individual in nature. Thus, in the CDR the tonus of small head vessels diminished the most at the beginning and end of the flight. In the FLE the deviations of indices of arterioles and veins of the right and left hemispheres varied in direction; however, their absolute values were within the range of preflight levels. The indices of tonus of leg vessels dropped appreciably at the start of the flight, as compared to base levels (with the exception of venous tonus of the FLE, which increased), and by the 119th day there was gradual return to values equaling preflight ones or exceeding them. The tonus of small arterial vessels of the forearm had a tendency toward some increase in both cosmonauts at the start of the flight, and it was more marked at the end. The changes demonstrated in weightlessness in hemodynamics and structure of the cardiac cycle were apparently due to two factors: elimination of hydrostatic pressure and, as a consequence, redistribution of blood and change in vascular tonus [10], as well as decrease in muscular exertion due to the diminished physical load and tension of tonic postural muscles [11].

The phasic nature of hemodynamic changes was the result of successive involvement of mechanisms of adaptation of the body to the new environmental conditions. As we know, hypervolemia of the upper part of the body is a consequence of redistribution of body fluids, in turn, hypervolemia is associated with the sensation of blood rushing to the head, facial edema, increased venous return of blood to the heart. Objectively, this was manifested by an increase in SV and MV, increased pulsed filling of head vessels and development of the volumetric load phase syndrome. The pressure in the venous system must become balanced, i.e., increase relatively in the central veins and right atrium, and decrease in peripheral veins [4]. The fact

that filling of jugular veins was increased during the 1st month of flight is an indirect confirmation of changes in venous pressure. This is indicated by the typical change on the jugular pulsogram (enlargement of presystolic and diastolic waves), as well as results of indirect measurement of venous pressure during decompression of the lower half of the body during long-term space flights [1].

As we know, elevation of pressure in the cardiopulmonary region is a stimulus for unloading reflexes, which are manifested by development of bradycardia, hypotension, deposition of blood and which lead to a decrease in venous return of blood to the right and left heart [12]. Evidently, these processes also affect changes in HR and AP, which were observed during the first month of flight and were more distinct in the CDR.

Subsequently, due to triggering of reflexes from the carotid sinus, there is probably establishment of a mode of system function that is balanced on a new level [13]. This is aided to some extent by elimination of some of the "excessive" fluid due to stimulation of diuresis, with involvement of the Henry-Gauer reflex or by some other means [14].

The change in phasic structure of the cardiac cycle, which was demonstrable over virtually the entire flight merits attention. Typically enough, reduction of the isometric phase and relative extension of the isotonic were reflected in the dynamics of diastolic phases: shortening of time of isometric relaxation and extension of phase of rapid filling. There are two ways to explain this. On the one hand, the possible increase in positive chronoinotropic influences on contractile function of the myocardium could be related to intensified activity of the adrenosympathetic system, which is manifested when more intensive physical training and operator work are performed. On the other hand, adaptation of myocardial function to the hemodynamic changes that are specific to weightlessness is a probable cause. It may be assumed that, in weightlessness, the exertions of tonic postural muscles are reduced to a minimum, and because of the constant underload the muscular system becomes deconditioned to some extent. These factors could diminish the activity of so-called "peripheral hearts" [15], which are involved in skeletal muscles in movement of blood from arteries, through capillaries, into veins, as well as the function of muscular venous pumps, which help in the venous return of blood to the right atrium [16]. Exclusion of these elements of circulation of blood over the vessels probably causes an increase in inotropic influences on myocardial function, with increase in rate of myocardial contraction and relaxation. This is manifested by the increase in force and efficiency of pre-ejection and ejection phases, on the one hand, and reorganization of diastolic structure, on the other.

The obtained data warrant the conclusion that changes in parameters of the cardiovascular system are functional in nature, and they show that man can adapt to weightlessness.

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CHANGES IN HEMOGLOBIN MASS DURING REAL AND SIMULATED SPACE FLIGHTS

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[Article by I. S. Balakhovskiy, V. I. Legen'kov and R. K. Kiselev, submitted 8 Jan 80]

[English abstract from source]

Following space missions of more than two weeks the hemoglobin content decreased. The largest reduction of this parameter was seen after flights of 1—2 months (25—33% of the initial value). In the recovery period the reticulocyte count increased reaching maximum at the end of the second and the beginning of the third week.

[Text] Only moderate, but not always consistent changes were demonstrated in studies of various aspects of metabolism during space flights. Thus, weight [mass] loss due to dehydration developed only during short-term flights. Only in such flights was it possible to demonstrate a reliable decrease in extracellular fluid [1, 2]. Blood urea level increased over a narrow range, but consistently [3, 4]; in most cases, cholesterol concentration decreased, but occasionally increased [3]. With regard to changes in endocrine indices, increased excretion of epinephrine, norepinephrine [5] and aldosterone [5, 6] were the most consistent ones. After the flights there was usually no increased elimination of 17-hydroxycorticosteroids. This led to the assumption of functional hypoadrenocorticism, since the end of a flight, which is a powerful stimulus, should have induced a nonspecific glucocorticoid reaction if there was preservation of functional reserves of the adrenal cortex [7]. According to existing publications, there was a decrease in potassium mass in all cosmonauts examined [8]; however, the small number of such studies does not enable us to derive definitive conclusions. After flights, a consistent increase in blood plasma creatinine kinase activity was observed, and this is understandable, since the activity of this enzyme always increases with increase in physical activity [9, 10].

Against this background, the consistent and reliable decrease in concentration and mass of hemoglobin is of utmost interest; it was demonstrated in all examined cosmonauts who had participated in flights lasting more than 2 weeks [11, 12]. Of all the metabolic changes found up to this time, this effect is the most specific for space flights.

P. A. Korzhuyev was the first to suggest in 1963 that there could be impairment of hemoglobin synthesis in weightlessness, on the basis of purely theoretical considerations [13, 14]. He believed that the absence of gravity would lead to dystrophic processes in bones, which must inevitably also affect the hemopoietic function of bone marrow. Concurrently with these theoretical studies, Soviet cosmonauts were found to have changes in red blood cells [12], while American researchers, who used radioactive isotopes, demonstrated a decrease in erythrocyte mass of crew members of Gemini-7 which was flown in 1965. We know from orthopedic works that people who have spent a long time on bed rest present a decrease in blood mass [15]. These facts and theoretical considerations prompted us to develop a rather simple and convenient method of assaying hemoglobin mass. The results of systematic studies using this metod are summarized here.

Methods

Cosmonauts were examined under hospital conditions before and after flights. Before the flights, most of them had been under observation for several years, and this enabled us to determine the hemoglobin mass inherent in each of them with reliability, the fluctuations thereof not exceeding 7-8%. Experiments involving long-term hypodynamia were conducted on young men, who had spent up to 1 month on strict bed rest and who receivied a diet that was similar in composition to the cosmonauts' flight rations. In some of the tests, the head end of the bed was dropped to an angle of about 6°. We assayed blood reticulocytes using the conventional method and hemoglobin mass by the carbon monoxide method. For this, the subject breathed with a mixture of air and a certain amount of carbon dioxide in a closed system. Hemoglobin mass was calculated from the increment of blood carboxyhemoglobin [16]. In order to elaborate standard indices and assess reproducibility of the method, we examined 267 men 18 to 60 years of age, whose hemoglobin mass constituted a mean of 736±75 g or 412±35 g/m^2 body surface. The scatter of individual data obtained in numerous tests on the same subject was characterized by a coefficient of variation of 2.4%.

Results and Discussion

Figure 1 illustrates the results of postflight testing of cosmonauts' hemoglobin mass. The first postflight examinations revealed a decrease in hemoglobin content in most cosmonauts, and it reached 25-33% of the base level. The decrease was at a maximum after flights lasting 1-2 months; no distinct stabilization of hemoglobin mass was observed with longer flights. For the first 2 postflight weeks, erythrocyte and peripheral blood hematocrit levels were reduced, then gradually rose. On the day they landed (0 day) and on the 1st postflight day, there was an increase in hematocrit in cosmonauts who had performed increased exercises in the readaptation period. This transient postflight thickening of blood disappeared after fluid intake.

On 0 day, the number of reticulocytes in peripheral blood was on the average about one-half the base value, which apparently reflects changes in inflight blood composition [11]. The readaptation period was characterized by a marked reticulocyte reaction. From the existing material, it was possible to demonstrate a correlation between the nature of this reaction, duration of flight and hemoglobin deficiency (see Table 1). In all cases where the tests were repeated over a rather long period of time, the maximum number of reticulocytes was found in the end of the 2d week

and beginning of the 3d week of the readaptation period. Not infrequently, the reticulocyte count was 5-7 times higher than the preflight level after long-term flights. We were impressed by the fact that there was faster development of the reticulocyte reaction after flights lasting over 3 months: already on the first postflight day the reticulocyte count reverted to normal, and by the 3d day it increased by 1.5-2 times.

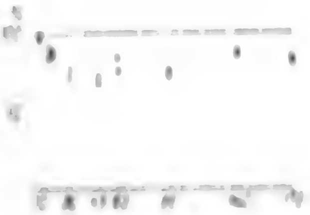

Figure 1.
Changes in hemoglobin mass after space flights
X-axis, duration of flight (days)
Y-axis, hemoglobin mass (% of base value)

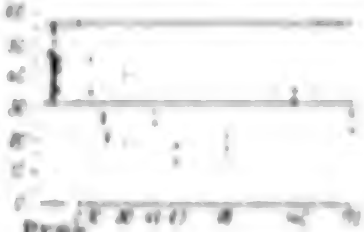

Figure 2.
Peripheral blood reticulocytes on 0 postflight day. X-axis same as in Figure 1.
Y-axis, reticulocyte count (thousands per μl)

Table 1. Nature of reticulocyte reaction as compared to hemoglobin deficiency immediately after flight

Flight time, days	Crew member	Hemoglobin deficit, %	Reticulocyte reaction		
			start, day	peak reaction, day	magnitude, % of preflight level
8	CDR	2		None	
	FLE	4		*	
16	CDR	15	5	5	123
	FLE	14	5	5	100
18	CDR	14	6	6	162
	FLE	14	6	6	130
30	CDR	14	0	12	337
	FLE	19	7	7	220
49	CDR	29	7	13	368
	FLE	33	7	15	376
63	CDR	16	7	16	176
	FLE	25	7	16	313
96	CDR	25	1	12	688
	FLE	26	1	12	531
140	CDR	16	1	25	438
	FLE	12	3	41	219
175	CDR	19	3	11	267
	FLE	18	3	11	166

The duration and severity of the reticulocyte reaction varied significantly. Considerable differences were observed in composition of blood of the same crew members

after 49- and 140-day flights. It must be noted that similar degrees of changes in metabolic parameters were not uncommonly demonstrated in previous studies on all crew members [7].

Table 2. Changes in erythrocyte mass of American astronauts

Program, orbital station	Duration of flight, days	Change in parameter, % initial value, $\bar{x}$ or $\bar{x}\pm\sigma$	Source
Gemini	From 4 to 14	−13.6±2.3	[2]
Apollo, with lunar landing	To 11–12	−7.4±1.2	[2]
Apollo, without lunar landing	To 11–12	−2.4±1.6	[2]
Skylab-2	28	−14.3	[23]
Skylab-3	59	−12.2	[23]

The decrease in hemoglobin mass during space flights was most probably due to inhibition of erythropoietic function of bone marrow. This is confirmed by the low reticulocyte levels in peripheral blood (Figure 2). There was negligible change in peripheral blood hemoglobin concentration, and this could occur only if there was concurrent decrease in plasma volume. Thus, simultaneously with inhibition of hemoglobin synthesis in weightlessness, there is apparently also inhibition of formation of serum albumin, which is the main protein of blood plasma.

The recovery process begins rapidly after termination of the flight. The increase in reticulocyte count is indicative of intensification of erythropoietic function of bone marrow. The direct change in hemoglobin mass is indicative of slow but consistent increase. In spite of this, the concentration of hemoglobin and number of erythrocytes in peripheral blood decrease for some time, reaching a minimum on the 9th-25th postflight day. This indicates that, at this time, blood plasma volume is restored faster than the globular part.

Our data are consistent with the results of American researchers, who studied erythrocyte mass volume at different times after a space flight using radioactive tracers (Table 2). Erythrocyte mass also diminished in American astronauts, though to a lesser extent than in Soviet cosmonauts. There was a well-marked postflight reticulocyte reaction. Thus, on the 21st postflight day, reticulocyte count reached 234% of the base level in the crew of Skylab-3.

Analogous changes were also demonstrated in studies involving simulated weightlessness by means of bed rest in horizontal or antiorthostatic [head end of bed tilted down] position. After spending 30 days under these conditions, there was also a decrease in hemoglobin and plasma volume, but to a lesser extent than after space flights (Table 3). The dynamics of the tested parameters of erythrocytes during the period of recovery after hypokinesia were generally similar to the postflight dynamics. The rather good similarity of reactions to real flight conditions and simulated flight conditions in laboratory experiments indicates that antiorthostatic hypokinesia can serve as a model for studying mechanisms of hemopoietic changes during space flights.

Table 3. Changes in mass and concentration of hemoglobin, and in reticulocyte count in studies involving 30-day hypokinesia ($\bar{X}\pm m$)

Series	Conditions	Number of subjects	Hemoglobin mass, g/m^2			Hemoglobin concentr., g%			Reticulocytes, $^0/_{00}$	
			before experim.	after 30-day experim.	14th-27th day of readapt.	before experim.	after 30-day experim.	14th-27th day of readapt.	before experim.	14th-27th day of readapt.
A	Horizontal hypokinesia	[illegible]	[illegible]	[illegible]		15.1±0.1	15.6±0.1	13.0±0.5**	5.2±0.7	[illegible]
B	Antiorthostatic hypokinesia (-6°)	[illegible]	[illegible]	[illegible]	[illegible]	14.4±0.2	17.0±0.5**	[illegible]±0.2	6.5±0.5	[illegible]
C	Control (usual motor activity)	15	[illegible]		[illegible]	14.2±0.2		14.1±0.1	[illegible]	[illegible]

*P<0.02 **P<0.001

The mechanism of the above-described changes cannot be related solely to hyperoxia, as it was originally assumed by American researchers [17, 18]. There was virtually no hyperoxia in the cabins of Soviet spacecraft, let alone the fact that there could not be any in the model studies.

The dynamics of changes in concentration of hemoglobin and reticulocyte count in peripheral blood were studied comprehensively at the early stage of antiorthostatic hypokinesia (Figure 3). During the first day the hemoglobin level rose significantly and remained high for the entire first week of the study. By the 4th day, most subjects presented different degrees of reduction of reticulocyte count in peripheral blood. Since overall hemoglobin mass could not change severely within several days, the increase in concentration of hemoglobin in peripheral blood apparently reflects a drastic decrease in plasma volume, which occurs consistently in such tests [19, 20].

Thickening [coagulation] of blood, which occurred on the 1st day of antiorthostatic hypokinesia may be the triggering mechanism of inhibition of erythropoiesis. Although hemoglobin content of blood was not determined on the first days of space flights, many of the results of model and postflight tests [1, 2, 22, 23] suggest that there was also a period of blood coagulation at the start of space flights.

With strict bed rest, it was possible to demonstrate by the method of tissue cultures not only a decline of erythropoietic activity but appearance of inhibitors of erythropoiesis on the 8th day. The inhibitor was usually not demonstrable after 1-1.5 months, while the subjects' plasma presented very little erythropoietic activity [24, 25]. After space flights, an increase in erythropoietic activity of plasma and urine was demonstrated by the method of testing on polycythemic hypoxic mice as early as 5-18 h after the end of the flight [11].

There have been previous indications of a link between blood hematocrit and synthesis

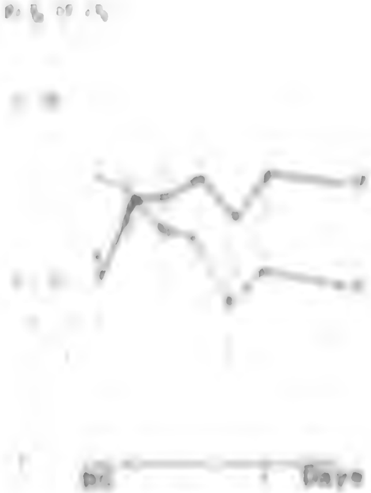

Figure 3.
Dynamics of reticulocyte count (Rt) and hemoglobin concentration (Hb) at early stage of antiorthostatic hypokinesia (AOH). X-axis, day of examination; BG--background

of substances that inhibit erythropoiesis (chalones) [26, 29]. One would think that these substances are synthesized on the first days of antiorthostatic hypokinesia, when there is considerable thickening of blood. Although concentration of blood at the start of space flights has not been demonstrated by direct measurements, it may be assumed that it is the main cause of inhibited hemopoiesis in weightlessness. This explanation appears more plausible than the one of P. A. Korzhuyev [13, 14], that hemopoiesis is inhibited under the influence of dystrophic processes in bone tissue. Indeed, there is a decrease in hemoglobin mass and reticulocyte count even after 2-week flights, when there are still no signs of dystrophic processes in bones.

The link between rate of production of hemoglobin and plasma proteins had not been studied heretofore. It apparently exists. In any case, there was simultaneous inhibition of hemoglobin and plasma protein synthesis both during flights and in model experiments. Dissociation between these processes occurred only in the readaptation period, and it was brief.

At the present time, the clinicophysiological significance of the described changes in hemoglobin mass and plasma volume cannot be evaluated exhaustively. On the one hand, the findings are favorable: with increase in duration of flights there is no proportionate progression of changes in hemoglobin mass. Recovery proceeds quite energetically, and although it requires over 1 month, it occurs without any complications and good well-being of the cosmonauts. On the other hand, the decrease in hemoglobin mass presents a hazard to the health of the cosmonauts, since it lowers the body's resistance to hemorrhages, which could be caused in flight by diverse unforeseen circumstances.

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THEORETICAL LEFT VENTRICULAR EJECTION PERIOD IN WEIGHTLESSNESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 20-23

[Article by V.A. Degtyarev, N. A. Lapshina and L. Ya. Andriyako, submitted 1 Jun 79]

[English abstract from source]

The relationship between duration of blood ejection and cardiac cycle at rest can be well described by a [illegible] function. This relationship is maintained in weightlessness as well. The derived formula used in calculations of the theoretical values of the ejection phase during an exposure to LBNP makes it possible to predict LBNP test tolerance [illegible] weightless state. The level of deviation of factual values of heart rate from theoretical values may be an additional index to be used in assessing health [illegible] of cosmonauts in flight.

[Text] The question of theoretical [proper] values of the main phases of the cardiac cycle is a rather important one. The degree of deviation of some parameter from its proper values could serve as one of the criteria in evaluating and prognosticating the condition of a subject. The function that determines the relationship between duration of the cardiac cycle (C) and period of ejection of blood by the left ventricle (EP) is among the most important functional relations. Determination of normal or proper values of EP for a given heart rate (HR) would enable us, for example, to differentiate between a reaction to a change in heart rhythm and reactions to changes in venous return, myocardial contractility and other important conditions of cardiac function.

A comparison of actual EP values found in cosmonauts at rest to the proper ones, which were calculated using formulas in the literature [1-4], revealed consistent differences between them. Moreover, in the case of some graded influence on the cardiovascular system, the dependence of EP on pulse rate may be other than at rest.

Our objective here was to find relationships between C and EP in resting cosmonauts and with the use of a functional test involving lower body negative pressure (LBNP).

Methods

EP was determined from the kinetocardiogram, recorded for the region of the apex beat. We tested 19 cosmonauts at rest, processed 330 preflight records and 180

in weightlessness. We tested 17 cosmonauts with LBNP, analyzing 300 preflight and 150 records in weightlessness.

We used a computer to analyze the relationships between two variables, C and EP. Equations of regression describing EP as a function of C were found as a result of this analysis.

Results and Discussion

Analysis of the data revealed that the relationship between C and EP can be described satisfactorily by an equation of linear regression. At rest, this equation has the following appearance:

$$EP = 0.183 + 0.098\ C \qquad (1)$$

Selection of coefficients of linear regression from data obtained at rest in weightlessness revealed that the relationship between the measured variables can be described by virtually the same formula as on the ground:

$$EP = 0.188 + 0.095\ C \qquad (2)$$

The maximum confidence interval for one subject did not exceed 0.025 s in both cases.

A comparison of the equations obtained to those proposed previously by V. L. Karpman [1] and I. Ye. Oranskiy [2] revealed that the lines of regression characterizing EP as a function of C are in an intermediate position in the cosmonauts (Figure 1). Thus, while the theoretical EP with C = 0.7 corresponds to 0.23 s according to V. L. Karpman and 0.27 s according to I. Ye. Oranskiy, it equals about 0.25 s in equations (1) and (2).

It can be stated that the nature of relationship between C and EP is retained in the absence of gravity, in spite of the fact that, in weightlessness, the cardiovascular system undergoes a change related to the adaptation process. The proper EP values in weightlessness can be calculated in practice using the formula found for earth's gravity.

With the use of LBNP under ground-based conditions, the relationship between C and EP can also be satisfactorily described by a linear function, but with different coefficients. The line of regression has a somewhat larger angle (Figure 2):

$$EP = 0.136 + 0.125\ C \qquad (3)$$

When there is good endurance of LBNP in weightlessness there is virtually no change in EP as a function of C (4). The values of EP are situated on the average only 0.005 s below the preflight ones (see Figure 2):

$$EP = 0.132 + 0.124\ C \qquad (4)$$

In both cases, the maximum confidence interval did not exceed 0.027 s.

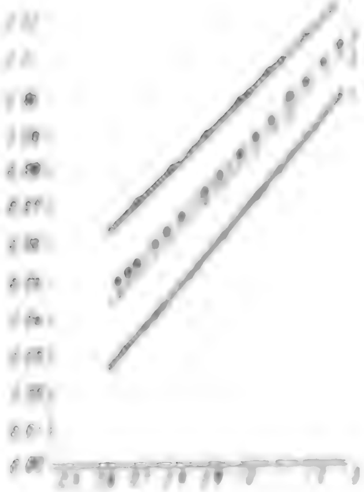

Figure 1.
Lines of regression characterizing EP as a function of C at rest
1) data of I. Ye. Oranskiy
2) preflight
3) inflight
4) data of V. L. Karpman

Here and in Figure 2: x-axis, C, s; y-axis, EP (in s)

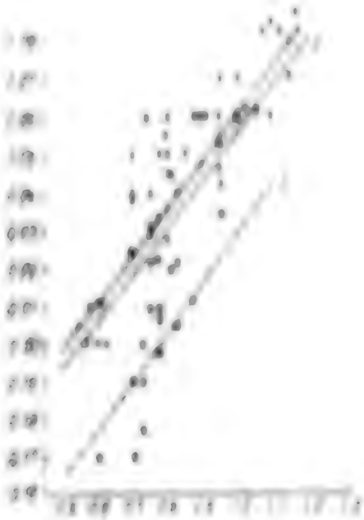

Figure 2.
Lines of regression characterizing EP as a function of C
1) with good enurance of LBNP test on the ground
2) with good endurance of LBNP in weightlessness
3) with orthostatic test
The dots indicate actual EP with good endurance and triangles with poor endurance of LBNP in weightlessness

Consequently, one can use the formula defined before the flight to evaluate EP changes under the influence of LBNP in weightlessness.

We know that the LBNP test in weightlessness is perceived by cosmonauts as a stronger factor than on earth [5]. In view of the more marked redistribution of blood and decrease in venous return, we could have expected substantial changes in the relationship between EP and C. However, this function remained unchanged, the only difference being that the theoretical "ground-based" EP point would be slightly higher than the "flight" point.

This relationship can probably be impaired in cases of poorer endurance of the factor or diminished orthostatic stability of the crew under the influence of space factors. Indeed, a comparison of the actual values of EP obtained in the case of diminished endurance of the test to the theoretical ones, determined with the above formula revealed that they differ substantially from one another. Figure 2 illustrates the position of actual EP values with normal and diminished endurance of LBNP in weightlessness in relation to the lines of regression corresponding to equations (3) and (4), as well as in relation to the line of regression determined for orthostatic conditions. With normal endurance of LBNP, the values of EP were within the range of the confidence interval; with diminished endurance they were considerably shorter than the theoretical ones and were close to the values inherent in the orthostatic test. This circumstance demonstrates once

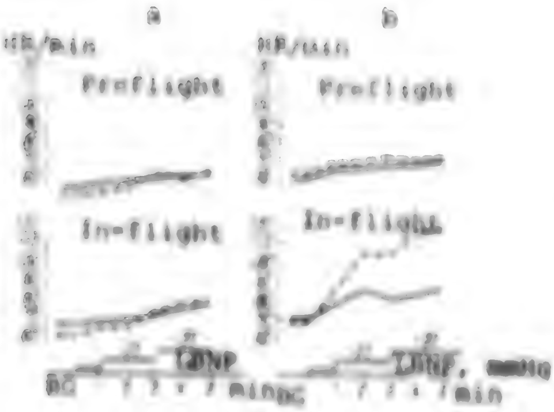

Figure 3.
Changes in heart rate with good (a) and poor (b) endurance of LBNP test. Solid lines refer to actual values and dash lines to theoretical ones; BG--background

more that there is more marked shortening of EP, which is closer to orthostatic, in the case of poor endurance of -35 mm Hg LBNP, although LBNP of -50 mm Hg is considered an analogue of the orthostatic test [7]. Evidently, the above distinction is also not specific to space flights. According to our findings [6], even on earth the reaction to -40 mm Hg with diminished endurance of LBNP was similar to the reaction to -50--60 mm Hg with good endurance of LBNP.

In the opinion of some researchers [8], one could set the concept of theoretical EP for a given HR during exposure to an orthostatic factor against the concept of theoretical HR with a given EP. Physiologically, this is quite justified, since EP is more closely related to changes in venous return during the orthostatic test or LBNP than to changes in HR. This approach to analysis enables us to take a different view of the pulse rate reaction to a postural factor. There are cases in the literature [9] indicating that the decrease in orthostatic tachycardia is not a positive phenomenon, and one can differentiate the orthostatic reaction from the deviation of theoretical HR with a given EP.

Analysis of our data from this vantage point revealed that differences in endurance of the LBNP test during flights can also be clearly differentiated on the basis of theoretical HR calculated for the demonstrated EP values using formula (3) or (4) (Figure 3).

In the case of good endurance of LBNP (see Figure 3a), the HR reaction conforms with its theoretical value, and the dynamics of decrease in blood flow rate do not differ substantially from preflight findings. With diminished endurance of the test, HR was actually much lower than the theoretical value (see Figure 3b). Consequently, estimation of duration of EP as compared to value of C is a rather reliable factor for assessing endurance of the LBNP test.

Thus, the degree of deviation of actual EP values or actual HR from theoretical values can serve as an additional criterion in evaluating the condition of cosmonauts during flights.

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SLEEP DISTINCTIONS, CIRCADIAN RHYTHM OF PHYSIOLOGICAL FUNCTIONS AND EFFICIENCY OF MAN ON FIRST DAY AFTER SHIFT IN SLEEPING-WAKING CYCLE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 23-28

[Article by A. N. Litsov, submitted 28 Nov 79]

[English abstract from source]

Physiological reactions of [illegible] male test subjects aged 25–42 were examined during the first day after a [illegible] to 11 hour work-rest cycle shift within 24 hours. The shift induced noticeable changes in sleep dynamics. Shifts close to inversion (9 and 11-hour) were accompanied by disturbances in the diurnal rhythm of heart rate and may cause deterioration of mental productivity. Negative effects of such time schedules need to be taken into consideration when developing work-rest regimens for representatives of various occupations.

[Text] Frequent changes in the work-rest schedule are one of the distinctions of many occupations (civil aviation flight personnel, industrial workers on different shifts, dispatchers, railroad workers, etc.).

Studies have established that the disturbances occurring in man with changes to new 24-h period schedules are not infrequently the immediate cause of diminished labor productivity and worsening of well-being [1-5]. It was found that the severity of these changes and rate of their disappearance in the course of adaptation are largely determined by the types of schedules used and, primarily, the correlation between "degree of shift and segmentation" of sleeping-waking cycles [1, 2, 6-8].

The significance of "degree of shift and segmentation" of sleeping-waking cycles to the process of man's adjustment to a new schedule and the role of such factors as structure of 24-h schedule, strictness and faithfulness of adherence to the daily schedule, individual biorhythmological distinctions, the pace of life of other people, motivation, etc., in adaptation were disclosed in previously published works [4-10]. In these studies, attention was devoted mainly to the changes in various body functions to conform with the new living schedule within the framework of long intervals (up to 2-4 or more weeks). At the same time, in practice it is sometimes necessary to make brief (up to 2-3 days) changes to a new schedule while performing complicated, emotionally charged, responsible work. Unfortunately, in most of the published works, relatively little attention, in our opinion, was devoted to the study of the early stage of adaptation to a new living schedule, so that we cannot predict accurately enough the dynamics of functional state and efficiency of operators under such conditions. Unquestionably, there is great

theoretical and practical interest in the study of initial human reactions when changing to a new sleeping-waking cycle.

Our objective here was to analyze the influence of changing from the usual sleeping-waking schedule to a shifted one on man.

Methods

We conducted the study on 35 healthy men ranging in age from 25 to 42 years, who were divided into 6 groups. For the first group (2 men) the schedule called for sleeping from 1000 to 1800 hours and being awake from 1800 to 1000 h. In the second group (12 men), sleep time was from 1400 to 2300 h and waking time from 2300 to 1400 h; in the third group (2 men), sleep time was from 1800 to 0200 h and waking time from 0200 to 1800; in the fourth group (8 men), sleep time was from 2300 to 0800 h and waking time from 0800 to 2300 h; in the fifth group (2 men), sleeping time from 0200 to 1000 h and waking time from 1000 to 0200 h; in the sixth group (9 men), sleeping time from 0500 to 1400 h and waking time from 1400 to 0500 h. In spite of the fact that the studies lasted 8 to 30 days, we analyzed the reactions immediately after changing to the new schedule, on the first day.

During these studies, the subjects were in an isolated room, with normal microclimate parameters and artificial light of 150-200 lux.

There was a strict schedule for the activities of each subject, and it was the same in structure with all modes, consisting of experimental psychological and physiological tests, physical exercise, transmission of reports, self-observation, self-service (preparing meals, personal hygiene, etc.).

During these studies, we recorded the following parameters: circadian rhythm of correlations (K) between integrated activity of fast ($\alpha + \beta$) and slow ($\theta + \delta$) waves on electroencephalograms (EEG), and heart rate (HR), averaged for 1 min; mental productivity (latency periods of simple and complex motor reactions, speed of arithmetic operations, accuracy of estimating a 20-s interval; quality and duration of sleep (according to EEG, actogram and subjective evaluation).

Results and Discussion

According to the data obtained, a shift to a new sleeping-waking schedule caused deviations in dynamics of the tested functions on the very first day. The chief ones were deviations in dynamics of sleep. Table 1 shows that rather good sleep was observed in only 3 subjects, who adhered to the ordinary daily schedule (4th group). In representatives of this grup, we could judge the normal course of sleep from the fact that they fell asleep rapidly (within 10-15 min), there was the usual correlation between slow-wave and paradoxical phases, and motor activity was low.

A shift to the left on the time scale of the sleep period caused it to worsen. Thus, when sleep was shifted by 5 h and the waking period was shortened to 11 h (3d group), the typical findings were an increase in falling asleep time to 60-80 min, intermittent sleep and prevalence of the superficial stages A, B, C), with high motor activity during the first half of the "night," on the one hand,

prevalence of deep slow-wave phases (D, E) and low motor activity during the second half of the "night," on the other hand.

Table 1. Results of study of sleep dynamics when subjects shifted from the usual sleeping-waking schedule

Parameter	Group					
	1	2	3	4	5	6
Falling asleep time, min	30 (10—50)	31 (20—40)	35 (25—40)	20 (7—25)	7 (5—9)	9 (2—10)
Total sleeping time, % of scheduled time	71.8 (68—75)	48.3 (17—75)	71.0 (67—75)	85.2 (67—92)	73.0 (66—80)	63.8 (44—81)
Calm 5-min periods, %	60.0 (44—76)	39.3 (25—72)	57.4 (45—70)	74.6 (39—80)	70.5 (61—80)	63.8 (37—73)
Movements/h	5.3 (3—7.6)	5.6 (4.1—10)	5.8 (4—9.4)	3.1 (2.1—5)	4.2 (3.3—5)	3.4 (3.6—11)
Superficial slow-wave EEG stages, %	75.9 (68—84)	84.7 (72—97)	52.1 (49—54)	53.4 (29—80)	45.4 (41—50)	67.4 (40—92)
Deep slow-wave EEG stages, %	19.3 (12—26)	7.3 (0—22)	31.2 (29—38)	28.0 (3—55)	35.2 (32—39)	24.3 (1—40)
Paradoxical phase, %	4.8 (4—6)	8.0 (0—12)	14.7 (13—17)	18.6 (8—36)	19.4 (19—20)	8.3 (3—17)

Note: Range of fluctuations is shown in parentheses.

A 9-h shift of the sleep period and shortening of waking period to 6 h (2d group) did not cause a significant increase in falling asleep time; however, sleep was brief (2-4 h) and superficial, the subjects woke up frequently and presented high motor activity. The men in this group were characterized by a polymorphic EEG pattern while asleep, with vagueness of different phases and changes therein. The correlation between deep slow-wave stages and the paradoxical phase was markedly diminished for the "night" as a whole. The subjects' own reports were also indicative of shortage of sleep in this group.

Somewhat different deviations of sleep dynamics were observed when the work and rest schedule was shifted in the opposite direction (to the right). Thus, when the subjects went to sleep at 0200 and waking period was extended to 19 h (5th group), most of them fell asleep rapidly (within 5-10 min), slept deeply and calmly to 0700-0900 h (i.e., they awoke 1-3 h earlier than the scheduled time). Deep slow-wave stages (D, E) and the paradoxical phase were prominent on the EEG.

With a 6-h shift of the sleep period to the right and extension of waking period to 22 h (6th group), even less time was required to fall asleep (up to 2-5 min), after which there was immediate deep sleep with relative prevalence of the paradoxical phase, which resembled morning sleep [9-12]. Such sleep lasted to 0700-0900 h, i.e., only 2-4 h. Subsequently, some of the subjects fell asleep again after a short wakeful period, but sleep was superficial and intermittent. Other representatives of this group did not fall asleep again until the end of the scheduled period after waking up. Nevertheless, according to the subjective evaluations of subjects in both the 5th and 6th groups, sleep was quite good over the "night" as a whole.

Distinct sleep disorders were observed in subjects who made an 11-h shift in sleep period and whose waking period was reduced to 3 h (1st group). In this group, we observed an increase in time required to fall asleep, to 50 min, superficial sleep,

with frequent awakening, high degree of motor activity and impairment of phase structure of sleep, which is reduced to 4-6 h.

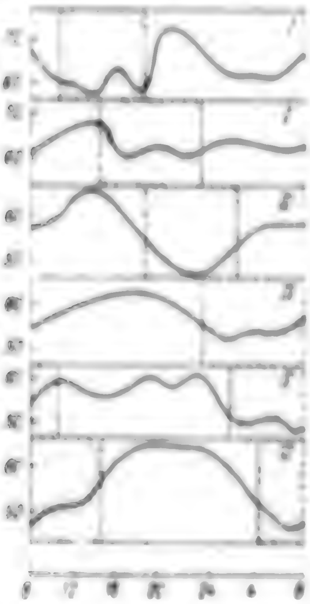

Figure 1.
Circadian dynamics of HR of subjects on different schedules with single alternation of sleeping and waking periods (mean data). Here and in Figure 2, 1st to 6th groups respectively. Striped areas indicate sleep periods.

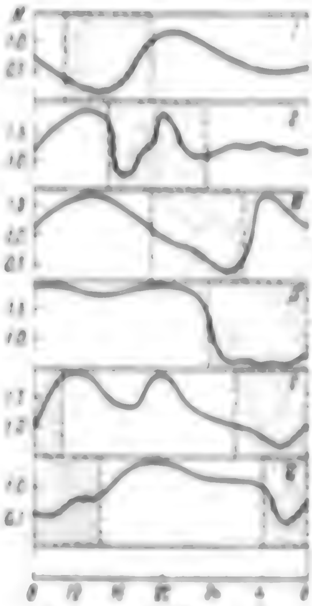

Figure 2.
Circadian dynamics of correlation between fast (α and β) and slow (θ and σ) EEG waves of subjects on different schedules with single alternation of sleeping and waking (Mean data).

$$K = \frac{\alpha+\beta}{\theta+\sigma}$$

Thus, analysis of the obtained data indicates that there is a change in sleep function immediately after changing to an unusual schedule, which is related to duration of prior waking period and direction of the shift of sleeping-waking cycle. When there is a shift to the right on the time scale and waking period is extended, the sleep disorders are referable primarily to the second half of the sleep period, which coincides with the waking period with the usual schedule [9, 12]. When the schedules involve a shift of sleep periods to the left and shorter waking periods, the first half of the sleep period is affected, primarily the process of falling asleep. As the phase shift nears inversion, the sleep disorders become more marked.

Some changes in circadian rhythm of HR and EEG are also observed with the change to a different living schedule. According to our findings (Figure 1), on the usual daily schedule (4th group), all subjects presented a distinct diurnal rhythm to pulse parameters with elevation of values in the daytime and decline at night. The very same changes were demonstrated in the dynamics of correlation between fast and slow EEG components (Figure 2).

The most noticeable disturbances of circadian rhythm of physiological parameters were noted in representatives of the 2d group (9-h shift to the left). The pulse

rate curve (see Figure 1) of these subjects was appreciably flatter than that of subjects in the 4th group (who can be considered as the standard in this case, since this curve was obtained on the normal living schedule), and the differences between sleeping and waking periods were very slight. An analogous comparison of the curves for subjects in the 2d and 4th groups in Figure 2 indicates that here too the difference between the two curves is significant, both with regard to general shape and correlation between values recorded during waking and sleeping periods.

Thus, a 9-h shift to the left of sleeping-waking rhythm was associated in our studies with marked disturbances referable to circadian dynamics of HR and EEG.

As can be seen in Figure 1, impairment of circadian rhythm of HR was also observed in the 1st group of subjects (11-h shift to the left). The circadian curve of individuals in this group was characterized by the presence of a segment with very low values in the middle of the waking period, between 0100 and 0600 on the local time scale. We do not observe such a decline of HR in the middle of the waking period on the usual schedule (see Figure 1, IV). The presence of two distinct minimums is also demonstrable on the curves reflecting the correlation between integrated activity of fast (α and β) and slow (θ and σ) EEG rhythms (see Figure 2, I). Consequently, the 11-h shift in sleeping-waking rhythm was associated with appreciable disturbances of circadian dynamics of HR and EEG parameters, just as we found with a 9-h shift. In the other cases (3-, 5- and 6-h shifts) we failed to demonstrate any significant disturbances of circadian rhythm of HR and EEG (see Figures 1 and 2): just like those of subjects in the 4th group, the curves for the 3d, 5th and 6th groups were characterized by an overt elevation of parameters during the waking period and decline during sleep.

Table 2. Dynamics of efficiency indicators of subjects when changing to a shifted sleeping-waking cycle

Parameter	Waking period h	Group					
		1	2	3	4	5	6
Simple motor reactions to photic stimuli, ms	1st	215	219	296	298	274	186
	5th	297	222	296	321	296	288
	10th	322	209	292	278	278	195
	15th	339	193	330	280	309	193
Reaction of choice to photic stimuli, ms	1st	467	347	568	512	505	402
	5th	548	385	577	452	579	382
	10th	602	356	589	437	506	385
	15th	540	361	503	460	502	397
Rate of performing arithmetic operations, s	1st	5.0	5.02	4.20	3.82	3.98	4.21
	5th	4.85	5.40	4.44	4.50	4.12	3.98
	10th	[illegible]	[illegible]	[illegible]	4.87	3.79	4.40
	15th	5.22	5.07	4.72	3.96	4.47	4.50
20-s time estimating test (deviation from specified), s	1st	[illegible]	1.56	4.95	2.84	1.84	[illegible]
	5th	[illegible]	1.74	[illegible]	[illegible]	2.31	[illegible]
	10th	3.08	2.23	1.03	3.48	4.20	2.36
	15th	4.32	2.94	2.00	2.73	1.02	2.43

The results of testing mental productivity of the subjects are listed in Table 2. The data in Table 2 indicate that subjects in the 1st and 2d groups definitely performed arithmetic operations more poorly than representatives of the 4th group.

Although we do not rule out individual differences in test achievement by members of different groups, we must note that the poorer results observed in the 1st and 2d groups in the middle and end of the waking period could be attributed to their change to an unusual living schedule with considerable phase shift. In the groups with smaller phase shifts (3d, 4th and 6th), the results of performing arithmetic operations did differ as unequivocally from the 4th group; however, even here (the only exception was the 5th group, with the smallest phase shift) arithmetic operations were performed worse in most cases than in the 4th group.

At the same time, several of the parameters of mental productivity of groups on a shifted sleeping-waking schedule were better than in the group with the usual schedule. Thus, the daytime dynamics of choice reaction were more distinct in the 2d and 6th groups than the 4th. As compared to the 4th group, the 6th presented obvious advantages as well in accuracy of estimating specified time intervals. We cannot rule out the possibility that mental productivity of man, referable to some forms of work, may remain on a high level on the first day after altering the living schedule, when the stress reaction is only starting to develop. Moreover, we know that man's productivity can improve with moderate stress; from this point of view, some stress is useful.

According to our data, intellectual operations pertaining to arithmetic are the most vulnerable on the first day after changing the living schedule. The test with arithmetic operations can be recommended, first of all, to assess man's mental productivity when living schedules are altered.

On the basis of the foregoing, it can be concluded that the use of schedules that differ from customary ones by shifts in sleeping-waking cycle of more than 3 h can lead to appreciable worsening of sleep, already on the first day of the new schedule. Phase shifts that are close to inversion (9- and 11-h) may be associated at this time with impairment of circadian dynamics of HR and some EEG features, as well as poorer performance of some intellectual operations. When there is a compulsory use of altered schedules in the work of representatives of various specialties, one must take into consideration the negative influence of such schedules on man.

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HISTAMINE AND SEROTONIN LEVELS IN MAN IN THE PRESENCE OF NERVOUS-EMOTIONAL STRESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 29-32

[Article by S. Kalandarov, I. D. Frenkel' and L. I. Nekrasova, submitted 26 Jan 79]

[English abstract from source]

Levels of histamine and serotonin in blood of test subjects kept on a Salyut space diet were measured during their simulated rise to an altitude of 8000 m, anticipation of exposure to acceleration, and mental work. During simulated rise the level of histamine increased and histamine-pexic activity of serum decreased. During anticipation of centrifugation the serotonin concentration grew. Levels of histamine and serotonin did not vary significantly in the test subjects kept on the space diet with certain food supplements.

[Text] There are data in the literature [1, 2] that indicate there is significant increase in blood serotonin and histamine content under the influence of nervous-emotional stress. The dynamics of metabolism of these substances are characterized by a prolonged aftereffect, which could cause allergic reactions [3, 4].

At the same time, there is virtually no information in the literature concerning histamine and serotonin levels as related to the combination of altred diet and nervous-emotional stress.

In this work, we studied the effects of conditions that cause stress on histamine and serotonin levels in blood. All of the subjects were on the diet worked out for the crew of the Salyut orbital station.

Methods

We conducted 2 60-day studies with the participation of 10 healthy males (5 in each) ranging in age from 23 to 41 years.

We selected models that simulate some of the situations inherent in space flights, related to elements of risk and unexpectedness, to reproduce neuroemotional stress under laboratory conditions.

In both studies, simulated ascent in a pressure chamber to an "altitude" of 8000 m, anticipation of accelerations on a centrifuge, as well as mental work (assignments varying in difficulty to be performed within a short time).

In the first study, the diet was based on a 6-day menu with food intake 4 times a day. The mean value of the daily ration constituted 3300 kcal. The diet contained 127 g protein, 134 g fat, 386 g carbohydrates, 2.9 g potassium, 4.0 g sodium, 0.7 g calcium, 1.73 g phosphorus and 0.4 g magnesium (according to analytical data). The diet was well balanced with respect to main nutrients, and included a vitamin supplement in the form of Undevit lozenges.

In the second study, the diet additionally included 3 sets of food supplements consisting of vitamins, glucose, minerals and phosphatide concentrate. The subjects were given these supplements for 5 days prior to each stress situation, as well as on the day of exposure to each of the stressors.

Blood histamine was assayed by the fluorimetric method of Shore et al. [5] and serotonin by the method of Shuder et al. as modified by V. I. Kulinskiy and L. S. Kostyukovskaya [6]. Concurrently we examined binding capacity (histaminopectic activity) in blood serum by the method of Parrot et al., as modified by V. I. Ivanitskiy [7].

Blood was taken for the tests on the day of exposure and 1 day after it (aftereffect period).

The obtained data were submitted to statistical processing. Reliability of differences was evaluated according to Student.

Results and Discussion

As can be seen in Figure 1A, there was some elevation of histamine level with simulation of ascent in the pressure chamber, particularly on the day of exposure ($P<0.05$). Concurrently there was a decrease ($P<0.02$) in histaminopectic activity of blood serum (Figure 2A).

When anticipating accelerations on the centrifuge and a mental load, there was a decrease in blood histamine content ($P<0.001$). During the aftereffect period we observed a tendency toward increase (normalization) of histamine concentration; however, histamine level remained lower than background levels (see Figure 1A). Histaminopectic activity of blood serum did not differ from normal (see Figure 2A).

Figure 1B shows that all three variants of stress situations had no appreciable effect on blood histamine content with the use of food supplements. There was only a slight elevation of histamine level with the 3d variant of stress situation, as well as in the aftereffect period following the first variant of stress. Histaminopectic activity also failed to change appreciably (Figure 2B).

Simulated ascent in the pressure chamber had no substantial effect on blood serotonin concentration both on the day of exposure and in the aftereffect period (Figure 3A). When anticipating accelerations on the centrifuge there was an increase in blood serotonin level ($P<0.01$ and $P<0.001$, respectively, on the day of exposure and in the aftereffect period).

With the third variant of stress, thre was some elevation of blood serotonin level on the day of exposure. Thereafter, the serotonin content decreased somewhat (see Figure 3A).

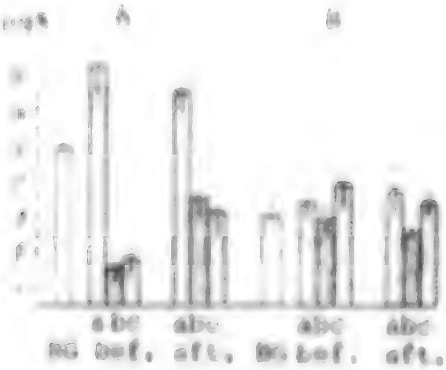

Figure 1.
Effect of different stressors on blood histamine content.

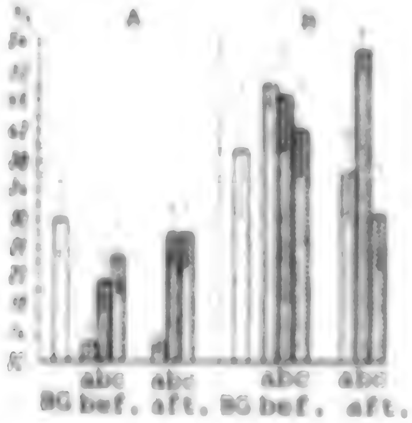

Figure 2
Effect of different stressors on binding capacity of histamine (histaminopexia)

Key (for Figures 1, 2 and 3):
- a) simulated ascent in pressure chamber
- b) anticipation of accelerations on centrifuge
- c) mental load
- A) first study
- B) second study

BG) background
bef.) before
aft.) after

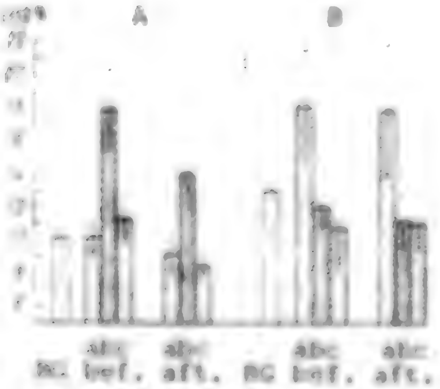

Figure 3.
Effects of several stressors on blood serotonin level

In the second study, where food supplements were used, there was some increase in serotonin concentration on the day of exposure to the first variant of a stress situation and in the aftereffect period. When anticipating accelerations on the centrifuge and mental work (second and third variants of stressors), we demonstrated, on the contrary, some decline of serotonin level at all tested times (Figure 3B).

Thus, with simulated ascent in the pressure chamber under the conditions of the first study, the concentration of blood histamine increased while histaminopectic activity decreased. When simulating an ascent in the pressure chamber with the use of food supplements (second study), histamine level and histaminopectic activity did not change. With other forms of stressors (anticipation of gravity loads on the centrifuge, mental work), under the conditions of both the first and second studies, there was a decrease in blood histamine content. Histaminopectic activity did not differ appreciably from its initial level.

Evidently, with simulated ascent in the pressure chamber a change occurs in correlations between histamine and its inactivating systems--diamine oxidase and histaminopectic activity. These data confirm the importance of taking into consideration not only changes in the substrate proper (histamine) but in enzyme-substrate correlations [8]. Not infrequently, phenomena inherent in histaminemia may be

encountered with different states of the organism, with relatively low blood histamine levels, but absence or attenuation of its inactivating mechanisms--diamine oxidase activity and histaminopectic activity [9]. This could cause an increase in biological activity of histamine and, consequently, alter the body's allergic background.

Apparently, the food supplements used in the second study were instrumental in restoring equilibrium in the system of histamine and its inactivating mechanisms, and led to a decrease in biological activity of histamine.

The results of this study are indicative of elevation of serotonin level when anticipating accelerations on the centrifuge in the first series. In the second one, we merely observed individual fluctuations in serotonin content of blood. Apparently, when expecting gravitational loads on the centrifuge, there was elevation of blood serotonin level as a result of diminished activity of the enzyme system, in particular monoamine oxidase [10, 11]. Evidently, the use of food supplements was instrumental in restoring equilibrium in the enzyme-serotonin system.

In view of the fact that the state of the body's endogenous environment is largely determined by the qualitative and quantitative composition of food, it can be assumed that alimentary factors are the most natural means of normalizing metabolic processes causing restoration of enzyme-biogenous amine relations.

Thus, nervous-emotional stress induced under the conditions of our studies by a simulated ascent in the pressure chamber and anticipation of gravitational loads on the centrifuge led to an increase in blood histamine and serotonin concentration. The nutrients (vitamins, glucose, minerals, phosphatide concentrate) used as dietary supplements prior to and during the period of stress situations had a corrective effect on the levels of the above-mentioned tissular hormones in blood.

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MOTOR ACTIVITY OF MAN WHEN IT IS ARTIFICIALLY RESTRICTED

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 32-35

[Article by N. Ye. Panferova and V. I. Pervushin, submitted 24 Aug 79]

[English abstract from source]

During a prolonged exposure to an altitude chamber (37–120 days) man's motor activity decreases 3 or 4 fold from 15–19 thous. to 2–4 thous. steps per day. During a prolonged restraint on a chair at the position of "an average physiological rest" the number of movements falls to 3–7 per hour. The change of motor activity during hypokinesia and recovery follows three stages: an acute change, a slow change, and a stage of stabilization at a new level. It has been shown that the people who find themselves in an environment limiting their physical activity do not have the need for an additional workload.

[Text] The question of dependence of motor activity on various environmental factors has not yet been sufficiently explored. The opinion is held that the level of motor activity remains constant for different animal species and that it is genetically determined by their size [1, 2]. In the works of A. D. Slonim [1], it was shown that when the movement of rodents is restricted, for example, by the size of their cages, the animals try to make up for the deficiency of movements by other forms of muscular activity (they begin to gnaw intensively on sticks, the cage and other objects). According to the studies of A. Ya. Gapon [3], people who lead a sedentary life also try to maintain their motor activity on the constant level inherent to each individual.

Under hypokinetic conditions there is drastic restriction of man's muscular activity. The question then arises as to the relationship between decline of muscular activity and degree of hypokinesia, as well as other conditions and factors. Our objective here was to investigate these questions.

Methods

We conducted two series of studies involving 8 healthy men 30-42 years of age.

In the first series, there was severe restriction of motor activity of the subjects (4 men) by means of a prolonged (5 days) stay in an armchair with specially selected angles to provide the position of "mean physiological rest," and the subjects

were not allowed to move. Motor activity was monitored by means of an actograph, whose sensor consisted of an inflated rubber pillow placed under the lumbar region. The actograms were recorded around the clock. We adhered to the usual schedule for the day, providing conditions for sleep at night.

In the second series, the subjects' muscular activity was restricted by the dimensions of a 50-m^3 pressure chamber, in which the subjects (4 men) remained around the clock: 2 of them for 120 days, 1 for 86 and 1 for 37 days. Their movements were not restricted and the conditions were about the same for all of them. The subjects were individuals involved in mental labor (physicians and engineers). In the pressure chamber, the work load consisted primarily of operator work, performance of psychophysiological tests and medical examinations, which took up 8-10 h per day. The parameters of the atmosphere differed from the usual ones in that there was a somewhat higher concentration of CO_2 (±0.5% fluctuations). In this series of studies, we used pedometers to determine the subjects' motor activity for 2 weeks before the study, during the stay in the chamber and after it. We kept a daily record of mean number of steps per day and determined the mean length of the steps.

It must be noted that the method we used to examine motor activity using pedometers is not without flaws. In particular, a pedometer reacts to any jolt of significant force in the vertical plane, including it in the reading of number of steps. At the same time, this instrument does not necessarily react to steps, if they are made smoothly, without a jerk. Nevertheless, we deemed it possible to use this method to study man's motor activity in the pressure chamber, in the belief that the above flaws would have the same influence on accuracy of measuring the number of steps before, during and after the test.

Results and Discussion

The results of these studies revealed that the subjects performed insignificant, often unconscious movements, the number, nature and intensity of which were unrelated to duration of hypokinesia, while seated in the chair under conditions of "average physiological rest" in spite of the rigid restriction of mobility (Table 1).

Table 1. Number of movements per hour during 5-day stay in chair in position of "average physiological rest"

Day of hypokinesia	Time of day			
	[illegible]	[illegible]	[illegible]	[illegible]
1st	9±1.[illegible]	11±1.0	11±1.9	10±1.7
2d	8±1.[illegible]	10±1.9	13±1.9*	11±2.2
3d	9±0.8	11±1.0*	13±1.6*	13±2.4
4th	8±1.0	11±0.6*	11±2.6	11±2.5
5th	7±1.8	11±0.9*	12±1.0*	13±2.0*

*Differences are reliable ($P<0.05$), as compared to the night (0100-0700 hours)

However, under these conditions, motor activity retained a distinct circadian rhythm, namely, it was minimal at night (7-9 movements per h) and reached maximum levels (11-13 and in some cases up to 24 movements per h) in the afternoon (20-70% more than at night).

Table 2. Mean daily number of steps taken before, during and after stay in pressure chamber (mean data for 1 week)

Subject	Before chamber	Time in pressure chamber, weeks																	After experim.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
P-n	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
K-v	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13 000
T-o	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					—	—
A-n	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—	—	—	—						12 900

Note: For technical reasons, we did not obtain information about motor activity of subject T-o after the study.

In the subjects involved in the second series of studies, motor activity ranged from 15,000 to 19,000 steps per day before the study, constituting a mean of 16,000 steps. At this time their motor activity was not restricted in any way. They performed their usual work and some light exercise.

When the subjects moved into the pressure chamber, there was drastic (3-4-fold) decrease in motor activity: by a mean of 12,000 steps on the 1st day, constituting 4000-5000 steps on the 2d day with slowly progressing decrease thereafter, followed by stabilization at 2000-4000 steps per day. It should be noted that the subjects had no active desire to be more active. However, on some of the days in the pressure chamber the level of activity rose, and this was related primarily to changes in working conditions. The number of steps increased with increase in work load, but did not exceed 6000 per day (Table 2). Maximum increase in activity was observed on the days that equipment was assembled and overhauled. The subjects sporadically performed brief morning exercises at their own initiative.

Since the dynamics of activity were in the same direction for all subjects, the obtained data were averaged, and they are illustrated in the Figure.

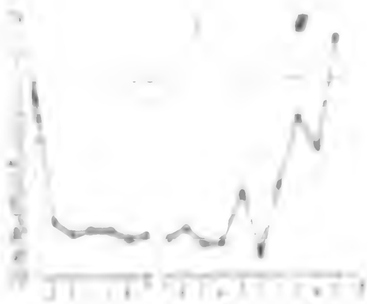
After the subjects came out of the pressure chamber and changed back to ordinary conditions, there was gradual restoration of activity within 8-13 days (see Figure).

It must be noted that not only the number of steps taken per day, but the length of the steps diminished (by a mean of 15%) while the subjects were in the pressure chamber.

The obtained data indicate that there is a significant decrease in man's motor activity when muscular activity is restricted. The degree of this decline is minimally related to time spent in the chamber.

In our studies, we failed to demonstrate any attempts on the part of the subjects to compensate for the diminished muscular activity.

although those involved in the second series of tests were allowed to exercise, and special exercisers were available to them. The decrease in motor activity in the pressure chamber is apparently the result of adaptation to hypodynamic conditions. Evidently, adaptation to these conditions is universal. It is related to changes in various body functions, including motor activity.



Dynamics of motor activity during long-term stay in pressure chamber (mean data for 3 subjects).
X-axis, day in pressure chamber; y-axis, steps (%) as compared to initial number before going into chamber

I) 7th day in chamber
II) 7 days before end of stay in chamber
III) 13th day after leaving pressure chamber

We can probably determine the number of movements constituting the biological minimum from the number of movements made while sleeping (see Table 1). It constituted 2-12 movements per h in the position of "mean physiological rest" and increased by 2-4 times in the waking state. The question of biological significance of these movements is not clear. Unquestionably, some of the movements are related to redistribution of supporting pressure on tissues in contact with the surface of the chair, as a result of which there could be some anemization of these tissues.

Man's adaptation to hypokinetic conditions, which is manifested by a decrease in motor activity, like the reverse process of readaptation, occurs in three stages. The first stage is the period of rapid adjustment, which lasted about 1 day (about 3 days for readaptation); the second is the period of slow changes (about 7 days; readaptation--up to 13 days). The third stage is the period of stabilization of motor activity on a new level.

When developing measures to prevent the deleterious effects of hypodynamia by means of physical exercises, one must take into consideration our findings, i.e., absence of a desire to be actively engaged in exercise in most people.

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MORPHOLOGICAL CHANGES IN DIFFERENT TYPES OF RAT MUSCLE FIBERS DURING LONG-TERM HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 35-41

[Article by S. Kurash, A. Andzheyevska and Ya. Gurski, submitted 2 Aug 79]

[English abstract from source]

[illegible]

[Text] There are many works dealing with changes in denervated muscles [1, 2], following tenotomy [1, 3] and after immobilization in a plaster cast [4, 5], but few of them deal with the influence of hypokinesia on morphological changes in skeletal muscles [6-8].

In this work, we studied the morphological changes in white, red and intermediate muscles.

Methods

The studies were conducted on 15 male Wistar rats initially weighing 260-280 g. For 30 days, 10 of the animals were kept in cages 18×4×5 cm in size, with access to feed (granulated feed for rodents) and water. After 30 days, the rats were put to sleep by means of supraperitoneal delivery of urethane. We took muscle sections by the identification method [9]: the topmost layer of musculus vastus lateralis (white muscle, which contracts rapidly and is glycolytic), the deepest layer of the same muscle (red muscle, which contracts rapidly and is oxygen-glycolytic) and musculus soleus (intermediate muscle, which contracts slowly and is of the oxygen type). Control material was taken from the same muscles of 5 rats of the same age. Sections for examination under a light microscope were fixed in 10% formalin solution, imbedded in a paraffin block, then stained with hematoxylin and eosin. Material for ultrastructural examination was fixed in 3.6% glutaric aldehyde on cacodyl buffer, pH 7.4, then in 1% osmium tetroxide on Milloniga buffer,

pH 7.4. After fixing and dehydration, the sections were imbedded in epon. After contrasting with uranyl acetate and lead citrate, ultrafine sections were viewed in a Tesla-613 electron microscope.

Results and Discussion

The findings using a light microscope revealed that the appearance of fibers in white muscle was generally correct. In only a few cases we demonstrated some increase in number of subsarcolemmic nuclei. There were irregularly occurring small perivascular accumulations of lymphocytes. No increase in amount of connective tissue between muscle fibers was observed.

Figure 1. Rat's white muscle

a) fragment of peripheral part of fiber without appreciable ultrastructural changes, magnification 9900 ×
b) correctly arranged sarcomeres; some slightly constricted myofibrils, magnification 9900 ×

We were impressed by differentiation of fiber diameter in red muscle. Along with a fascicle of properly assembled fibers, we observed fascicles, in which some of the fibers and sometimes all of them had a reduced diameter. The sarcoplasm of the narrower fibers was slightly basophilic. Striations were somewhat effaced in many places. There was an increase in number of nuclei under the sarcolemma and there were nuclei in the middle of the muscle fiber. Occasionally, these nuclei formed

shorter or longer rows. Some of them presented signs of pyknosis, others were larger, vesicular, with a distinct nucleolus. Focal, granular and clumped disintegration of sarcoplasm, with macrophages, was observable within isolated muscle fibers. In the endomysium there was some increase in amount of connective tissue, and in some areas there was a build-up of lymphocytes and macrophages. In the soleus muscle, the diameter of most fibers was smaller than in normal muscles. Some of them were very narrow, with basophilic sarcoplasm. Many presented changes in the nature of vacuolar degeneration. There was frequent clumped disintegration of sarcoplasm, with cellular phagocytes within the injured fibers. An increased number of nuclei was observed under the sarcolemma in many sites, with displacement in the direction of the middle of the fiber and formation of nuclear rows. Nuclei that formed rows were usually somewhat enlarged, vesiculate and had a distinct nucleolus. There was an increased amount of connective tissue within the endomysium; in some places there were small lymphocytic, histiocytic infiltrates and neutrophil granulocytes.

Electron microscopy revealed that most white muscle fibers had the proper ultrafine structure. The myofibrils were uniformly distributed, with well-preserved structure of sarcomeres. There was a small number of small mitochondria. Glycogen granules were found between the myofibrils, with a well-preserved system of tubules of the sarcoplasmic reticulum and triads. The nuclei were on the periphery of the fibers and presented correctly arranged nuclear chromatin (Figure 1). In some fibers, the myofibrils were distinctly narrower than in the control muscle (see Figure 1). Occasionally, there were minor deviations in arrangement of Z bands, as well as I bands. In some fibers, there was negligible dilatation of tubules of the sarcoplasmic reticulum, as well as clearing of the mitochondrial matrix. Elements of connective tissue (a small amount) and capillaries with normal appearance were demonstrable between the muscle fibers.

In red muscle, most of the muscle fibers presented the usual ultrafine structure; however, various forms of degeneration were found in many fibers. The most significant changes were referable to contractile elements. Occasionally, the myofibrils were spread out, the spaces between them were occupied by sarcoplasm of diminished electron density with a few glycogen granules, irregularly arranged tubules of the sarcoplasmic reticulum, remnants of triads and damaged mitochondria. Considerable disturbances, consisting of dilatation, diminished electron density, breakdown and "diffusion," were demonstrated in the appearance and lumen of the bands in some areas. This was often associated with complete destruction of myofibrillar structure, most marked in the peripheral part of the fiber (Figure 2a). In the place of the destroyed parts of the fibers there were dilated tubules of the sarcoplasmic reticulum, occasionally so-called membranous bodies, free glycogen granules, cisterns containing glycogen, as well as different sized vacuoles, often containing a fine-grain substance and membranous structures (Figure 2б).

In addition to mitochondrial changes, we demonstrated considerable lesions. The cell nuclei of fibers with signs of degeneration often presented irregular shapes, with numerous concavities in the nuclear membrane. In some nuclei, chromatin had less electron density, while the space between lamina of the nuclear membrane was irregularly dilated. There were isolated supernumerary cells (Figure 2в). There was an increased number of fibroblasts between muscle fibers, as well as intercellular substance of connective tissue, particularly in the vicinity of fibers with degenerative changes (Figure 2г). We were impressed by the significant dilatation of the intraplasmic reticulum, occasionally with very wide ducts, within the fibroblasts.

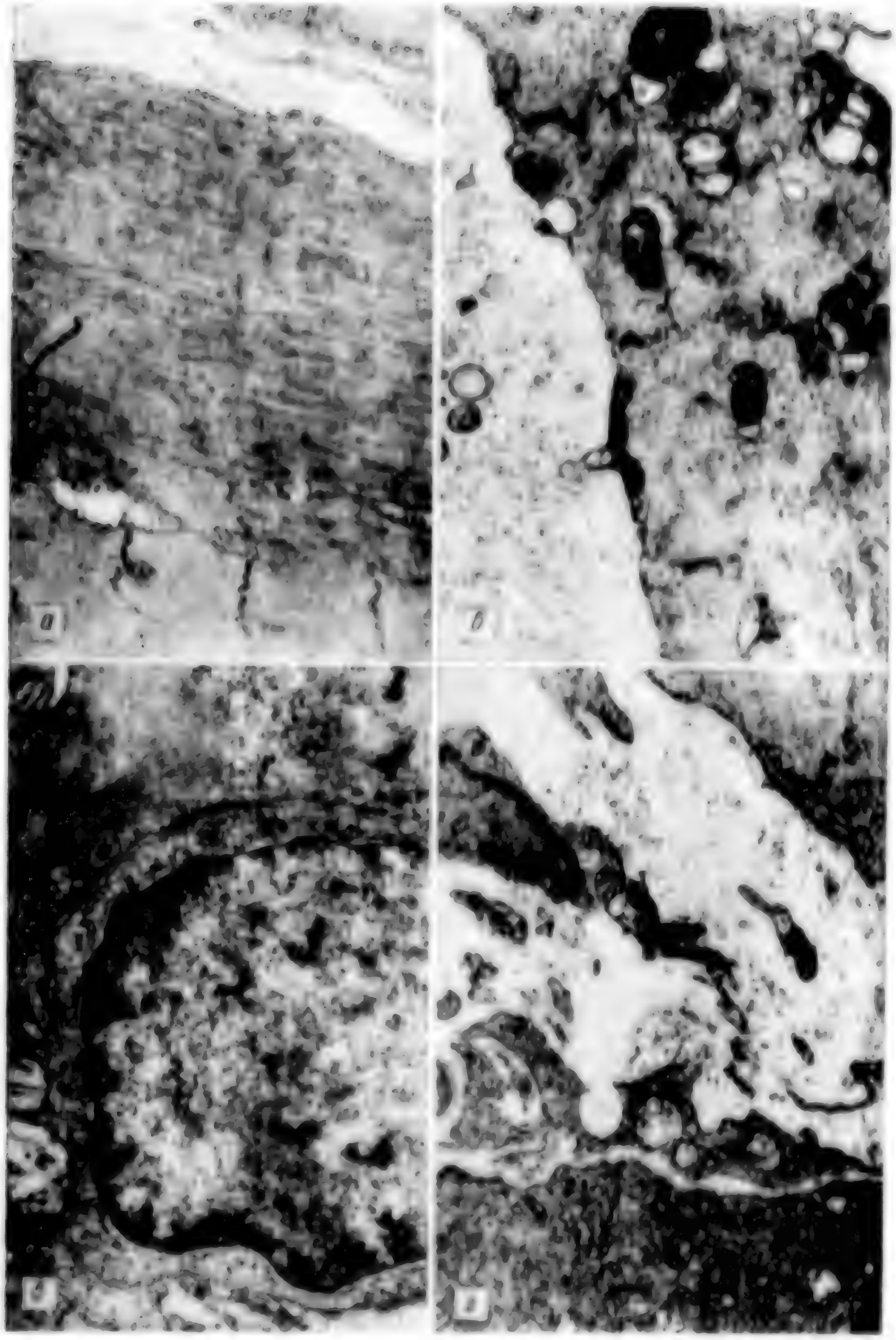

Figure 2. Rat's red muscle

а) significant damage to peripheral part of fibers with diffuse fibrillar structure, as well as fragmentation and "melting" of Z band; magnification 4750×

б) significant damage to myofibrillar structure, and many vaculoes; some contain fine-grain substance and membranous elements; magnification 9900×

в) satellite cell; magnification 7200×

г) increased amount of connective tissue near injured muscle fibers; 4750×

In the intermediate muscle, many muscle fibers presented degenerative changes and atrophy. The degenerative changes affected all elements of structural fibers. Myofibrils were usually involved in the peripheral part of the fibers. The lesions consisted of irregular course of Z band, separation or "melting" thereof over the entire surface of a destroyed sarcomere (Figure 10). In the areas subject to the greatest changes we observed fine-grain substance with membranous elements submerged in it (Figure 9). Other forms of lesions consisted of changes in the mitochondria, manifested by separation and homogenization of crests, clearing of mitochondrial matrix (Figure 11). There was a diminished amount of glycogen in the damaged fibers. In some areas there was dilatation of tubules of the sarcoplasmic reticulum and very marked vacuolar degeneration. The changes within the muscle nuclei did not differ from those in red muscle. There were slightly more supernumerary cells than in red muscle. We were impressed by the rather numerous narrow muscle fibers with nuclei arranged in rows and few myofibrils (Figure 12). Some of these fibers presented very marked degenerative changes. There was a rather large amount of connective tissue around the muscle fibers.

It is known that skeletal muscles are characterized by great sensitivity to deleterious factors. There are many pathological states that lead to muscle fiber atrophy. Most often, the causes are injuries to innervation, physiological aging and inactivity [7, 8, 10, 11]. The sensitivity of muscle fibers to deleterious factors is not always the same [5, 10, 12]. This is also confirmed by the results of our studies, which show that the morphological response of skeletal muscles to immobilization is closely related to their histological type. The soleus was found to be the most sensitive, representing mainly the intermediate type of fibers, in which the degenerative changes were referable to most fibers and all structural elements. The sensitivity of this muscle to immobilization has also been reported by other authors [4, 5, 7, 8, 11, 13].

It is generally believed that atrophy due to hypokinesia is manifested primarily by a decrease in amount of sarcoplasm, while myofibrils are atrophied at the final stage and to a minor extent [10]. The results of our studies, however, indicate that the most appreciable changes are referable to contractile elements. Pellegrino et al. [12] believed that the Z bands are the first to be damaged in the presence of diverse atrophies. The disturbances we observed in the system of Z bands, even in the least damaged white muscles, dilatation thereof, reduction of electron density and "diffusion" line in red muscles, as well as total disintegration in intermediate muscle could serve as evidence of this. These changes were often associated with destruction of myofibrillar structure. The results of our studies differ from the findings of Tomanek et al. [5], who believe that the myofibrils in red muscles retain their parallel arrangement of filaments, and bands thereof are demonstrable up to the late stages of degeneration during immobilization.

In addition to changes in myofibrils, we often observed dilatation of tubules of the sarcoplasmic reticulum. Vesiculation and significant dilatation of the reticulum are very typical of muscular atrophy due to denervation [2, 12, 14]. However, the changes we observed were not as severe as reported by the above-mentioned authors. This is no doubt related to the fact that immobilization diminishes the influx of nervous impulses, but does not eliminate them entirely. We also observed mitochondrial lesions due to immobilization of muscles. In the opinion of some authors [7, 12], the mitochondrial changes present a relative lag in comparison to atrophy as

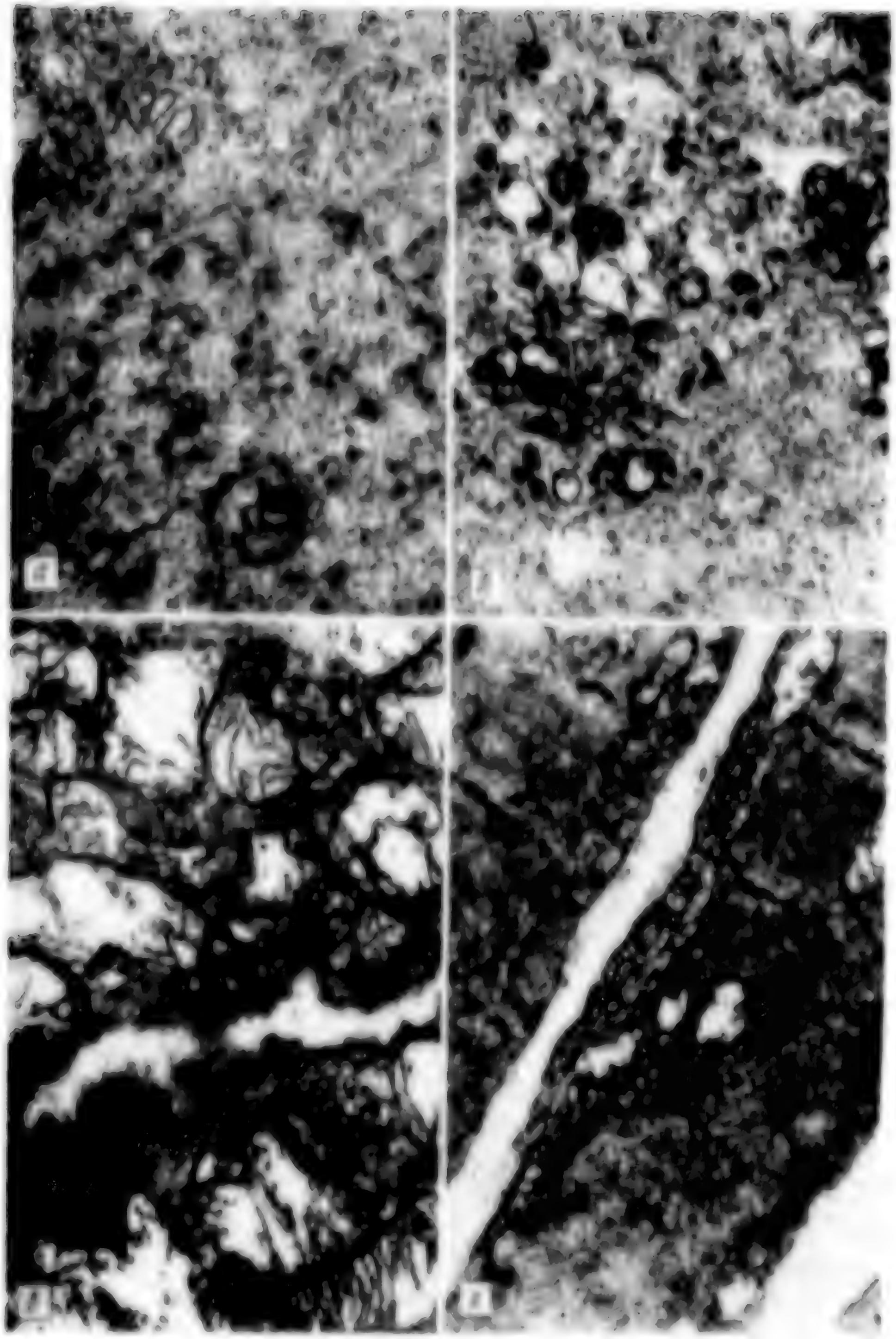

Figure 3. Rat's intermediate muscle

a) considerable damage to fiber with defragmentation and "melting" Z band over the entire surface of destroyed sarcomeres; magnification 9900×

b) fine-grain substance with submerged membranous elements in the place of destroyed myofibrils; magnification 14,400×

c) damage to many mitochondria with clearing of matrix and rupture of their crests; magnification 9900×

d) very thin muscle fibers with damaged mitochondria; magnification 4750×

a result of denervation. V. V. Portugalov [6], who studied the mouse quadriceps after immobilization in small cages, demonstrated that mitochondria were also considerably damaged in fibers where changes prevailed within the myofibrils. In other fibers he observed accumulation of mitochondria under the sarcolemma and an increase in number of cresta. We demonstrated relatively minor changes within the nuclei of muscle fibers. In red and intermediate muscles, we often observed an increase in number of nuclei under the sarcolemma, as well as a shift thereof in the direction of the middle of the fiber, with formation of nuclear rows. This phenomenon, which has been found in the presence of many pathological states [15-17], has still not been explained. Tomanek and Lund, like V. V. Portugalov [6], failed to demonstrate substantial structural changes in the nuclei of immobilized muscles. Supernumerary cells were occasionally found in both red and intermediate muscles. These mononuclear cells, situated within the main sheath of muscle fibers or surrounded by it, were capable of mitotic division [18, 19]. Their number increases in damaged fibers [19].

The degenerative changes within muscle fibers were associated with an increase in amount of connective tissue in their vicinity, and they were the most distinct in red and intermediate muscles. This confirms the results of biochemical studies of other authors [5], who demonstrated a 3-fold increase in concentration of hydroxyproline--an indicator of collagen content--in the soleus muscle of immobilized animals, and to a somewhat lesser extent in red muscle, but they failed to demonstrate appreciable changes in white muscle.

The significant lesions in fibers of red and intermediate muscles following hypokinesia indicate that restriction of motor activity is one of the factors in the etiology of pathological changes in muscles.

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CORTICOSTEROID CONTENT OF RAT ADRENALS IN THE PRESENCE OF HYPOKINESIA COMBINED WITH GRADED PHYSICAL EXERCISE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 41-44

[Article by Ye. A. Zagorskaya, submitted 12 Jun 79]

[English abstract from source]

The paper presents data on the content of corticosteroids in adrenals of rats exposed to 46-, 53- and 60-day hypokinesia as well as to 60-day hypokinesia combined with graded exercise. It was found that the content of corticosteroids in adrenals remained essentially unaltered after 46-day hypokinesia, decreased after 53-day hypokinesia and increased after 60-day hypokinesia as compared to the appropriate controls. The use of exercises demonstrated good reserve capabilities of the hypophyseal-adrenal system of rats after 60-day hypokinesia and revealed certain changes in regulatory mechanisms of the hypophysis—adrenal cortex system.

[Text] We examined adrenocortical activity of rats submitted to long-term hypokinesia. Graded exercise was used as a functional test to demonstrate the reserve capabilities of mechanisms that regulate corticoid activity.

Methods

We conducted two series of experiments during the same time of year, in May and June, on male albino Wistar rats with initial weight of 150-180 g. Control animals were kept in the usual vivarium, while experimental ones were kept in individual box-cages to limit their movements. In the first series of experiments, hypokinesia lasted 46, 53 and 60 days for the experimental rats. The animals submitted to 60-day hypokinesia performed graded exercise, running on a treadmill for 10-15 min, with the belt moving 18 m/min, once just before they were sacrificed. In the second series of experiments, the animals were submitted to hypokinesia for 53 and 60 days. The animals submitted to 6-day hypokinesia performed the same exercise as the rats in the first series, but did so daily for 8 days before they w : sacrificed. Rats exercised in the same mode served as vivarium controls. In both experimental series, the groups consisted of 4-10 animals each. After decapitation, we extracted the adrenals, which were cleaned, weighed and stored in a frozen state at -20°C for 1 month until they were treated.

In the first series, we studied the amounts of different corticosteroid fractions in each pair of adrenals by means of densitometry after chromatographic separation

Corticosteroid content in adrenals of control rats and rats submitted to hypokinesia for 46, 53 and 60 days (M±m)

Experimental conditions		First series				Second series		
Hypokin., days	Animal group	ratio of adrenal wt. to 100 g body wt.	corticosteroids, µg/100 mg tissue: corticosterone	dehydrocorticost.	DOC	ratio of adrenal wt. to 100 g body wt.	11-OC content: µg/per adrenal	µg/100 mg adrenal
46	Control	[illegible]	[illegible]	[illegible]	[illegible]			
	Experiment	[illegible]	[illegible]	[illegible]	[illegible]			
53	Control	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Experiment	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	Control	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Experiment	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	Vivarium+treadmill					[illegible]	[illegible]	[illegible]
60	Hypokinesia+treadmill					[illegible]	[illegible]	[illegible]

Note: 1, 2 and 3 asterisks indicate reliability of differences (P<0.05, P<0.01 and P<0.001, respectively) from corresponding control. The data are given in the form of averaged values, since the 11-oxycorticoid levels were virtually the same in the left and right adrenal

on a thin layer of silica gel. To improve sensitivity of assays, we added a solution of tetrazolium blue [1-3] to a suspension applied to a plate. In the second series, in view of the low levels of some corticosteroid fractions in the adrenals and related significant variability of individual parameters, we determined the overall 11-oxycorticoid (11-OC) fraction. 11-OC was assayed spectrofluorometrically in each adrenal separately [4-6].

Results and Discussion

The Table lists the results we obtained. There was no appreciable change in ratio of adrenal weight to 100 g body weight in any of the groups of experimental animals, which was indicative of absence of signs of hypotrophy or hypertrophy of the glands under the experimental conditions. In the first series of experiments, three fractions of compounds were differentiated at each tested time, and they coincided in mobility with standards for corticosterone, 11-dehydrocorticosterone and 11-deoxycorticosterone (DOC). The corticosterone and DOC fractions were demonstrated in largest amounts, in both control and experimental animals.

In rats submitted to 46-day hypokinesia, the absolute levels of the 3 hormonal fractions underwent virtually no change, or else there was a negligible decline, as compared to the corresponding control. In the case of 53-day hypokinesia, there was insignificant but reliable decrease in corticosteroid content of rat adrenals in both series of experiments. After 60 days of restricted mobility, the animals studied in the first series presented an increase in corticosteroid content, mainly referable to the corticosterone fraction. At the same period, 11-OC content of experimental rats tested in the second series of experiments, without exercise, almost doubled, as compared to the control. The increase was reliable when scaled to 100 mg adrenal tissue and, in all likelihood, it was due to increased biosynthesis of corticosterone. The combination of 60-day hypokinesia and graded exercise

was associated with further reliable increase in 11-OC content of the adrenals, as compared to the corresponding control and levels in experimental animals submitted to 60-day hypokinesia without exercise. It should be noted that 11-OC level also plays a role in the adrenals of the rats in the vivarium+treadmill group, as compared to animals in the vivarium control who did not exercise. However, the adrenal reaction to exercise in rats submitted to 60-day hypokinesia was considerably greater in intensity than in animals whose motor activity was not restricted.

The dynamics we demonstrated in corticosteroid content are apparently indicative of a certain periodicity of corticoid function during long-term hypokinesia. In view of some data in the literature [7-9], it may be assumed that the decline of corticosteroids on the 30th day of hypokinesia was preceded by a phase of elevation thereof in the adrenals at the earlier stages of the experiment.

The increase in adrenal corticosteroid content after 60 days of "pure" hypokinesia is indicative of preservation of the ability of these glands for steroidogenesis on a rather high level. Subsequent, almost 2-fold increase in 11-OC in the adrenals of these rats in response to exercise demonstrates that the reserve capabilities of the hypophysis-adrenal cortex system are intact. However, the greater reaction of experimental animals to exercise than in the corresponding control is indicative of certain changes in adaptational mechanisms of the organism. Such an increase in sensitivity of the adrenohypophysial system in the presence of a long-term stressor has also been reported by other authors [10-12].

The obtained data indicate that rats retain the reserve capabilities of the adrenohypophyseal system during 60-day hypokinesia, but there are changes in the mechanisms of regulating this system.

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COMPARATIVE EFFICACY OF VARIOUS BIOLOGICALLY ACTIVE COMPOUNDS DURING EXERCISE

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pp 44-51

[Article by V. S. Shashkov and N. G. Lakota, submitted 25 Feb 80]

[English abstract from source]

[illegible]

[Text] The tasks of a new scientific direction, pharmacology of healthy man, whose vital functions occur under physiologically deleterious living conditions or with maximum tension of functional, humoral and integrative systems of the body, have now been formulated in applied areas of medicine (space, sports) [1-6]. Questions of correction of efficiency, enhancing the body's general resistance, broadening adaptational capabilities and speeding up recovery processes are inseparably interrelated [7].

All this led to the need for a new evaluation of many biologically active compounds used in therapeutic practice. There are reports of the results of such studies in the literature; however, most products were used once and without pharmacological testing of the effect [8-12]. Current conceptions of physical fitness as a category consisting of three main elements--energy-forming capacity of the body, neuromuscular function and psychological factors [13]--served as the basis for a comparative evaluation of a large group of drugs referable to different classes, having defined their composition and methods of evaluating the stimulating effect.

Methods

We tested over 30 products and prescriptions using 640 sets of functional tests on 63 male volunteers ranging in age from 23 to 40 years, on a bicycle ergometer, under the usual conditions of vital functions (Table 1). Background data were obtained 2-3 times before and after the [illegible], at the start of which we evaluated individual reactivity to the products used. With single intake of central nervous system (CNS) stimulants, we conducted the tests at the time of maximum pharmacological effect. We concentrated mainly on giving courses of products, with successive and concurrent addition of different ones, after which they were evaluated on the basis of the set of tests. The last one included the well-known PWC_{170} [14, 15] and the "individual endurance" (IE) test that we introduced, with recording of heart rate (HR) on a pulse tachometer and exchange of gases on a Spirolit instrument. Intensity of exercise for IE was selected on the basis of individual PWC_{170} in such a manner that the HR would not exceed the aerobic threshold of 130-140 per min during the first few minutes [16], which would constitute $0.765 \; PWC_{170}$ on the linear segment of HR as a function of exercise load, after making the calculation using the following formula:

$$IE = \frac{PWC_{170} \cdot 130}{170}$$

A constant intensity of exercise was continued from the time of fatigue of external respiration to triggering of anaerobic capacity of the body and to maximum aerobic productivity with submaximum HR and maximum O_2 uptake [16, 17], the only indisputable criterion for comparing variations of physical fitness and stimulating effect [13, 18]. A 3-min spurt at the end of the exercise served as a control of proper selection of work load and time of stopping exercise.

Table 2 lists the parameters with a set of two tests that have been recognized as criteria for assessing the efficacy of pharmacological products. The results of prior studies in the area of hypokinesia with the participation of volunteer athletes [19] and the present study enabled us to give them ranks: "zero effect" (0), "significant stimulating or inhibiting effect" (±) and "considerable effect" (±II).

Results and Discussion

In the course of these studies, we solved several special problems:

It was established that the numerical values of PWC_{170} during the test with measurement of gas exchange were 10% lower than the standard values for conditioned subjects and 20% lower for those unconditioned to respiration with forced ventilation (8 and 17 people in the group, respectively).

The numerical value of PWC_{170} failed to reflect the true level of fitness to such an extent with intake of products that have a direct effect on HR (anaprilin--slowing; phenamine, metamphetamine, ephedrine and sydnocarb--acceleration), that this test is not proper for evaluation of the effect.

The mean statistical data on the new IE test (63 individuals of average physical development) were as follows: work time 28±10 min; intensity

850'100 kg-m/min, volume of work 30,000 kg-m, end HR 178-184/min, HR per spurt 190-210/min (the second figures refer to individuals with better physical conditioning).

With single intake of products of the doping type (group I), we observed an increase in IE time: by 37% with intake of epherine + strychnine, 21% with phenamine, 18% with metamphetamine, 16% with ephedrine and 11% with sydnocarb. When a course of CNS stimulants (phenamine and metamphetamine are contraindicated for such courses), maximum increase in efficiency was noted after intake of a mixture of ephedrine and strychnine (15% PWC_{170}, 16% IE). With administration of a course of therapy with small doses of the mixture, the doping effects of ephedrine disappeared (background level of HR at rest, during exercise and in the recovery period). Separate and combined courses of ephedrine and strychnine were favorably rated by the subjects, who observed increase in general tonus and appetite, with postponement of fatigue limit under ordinary conditions of vital functions.

A course of sydnocarb revealed that this product is a rather strong stimulant that is acutely related to dosage and requires strict individualization. Most subjects presented worsening of well-being, palpitations, increased perspiration and at times severe weakness. Objectively, the doping effects of a single dose persisted, according to the PWC_{170} test: increased HR at rest, during exercise and in the recovery period; according to the IE test: unreliable increase in performance time, which was associated with diminished mean O_2 uptake per load. Successive inclusion of sydnocarb to courses of amino acids and anabolics led to analogous reactions. Evidently, it is premature to recommend sydnocarb at the present time for space medicine.

With regard to the group of adaptogens (Table 3, group II), we compared to the effects of eleuterococcus to a relatively new product (saparal [derived from roots of Aralia mandschurica Rupr. et Max., with all ABC triterpene saponins]) and one that is being evaluated in a new aspect for the first time, Lagochilus inebrians [semifrutex of Labiatae family]. The results obtained from the set of both tests (minimal increment of efficiency parameters, but faster recovery processes according to HR and oxygen debit) confirmed entirely the existing conceptions about the expected effect and constituted an excellent recommendation of the method, with regard to its accuracy. Among the adaptogens, lagochilus is in first place, with regard to stimulating effect, and it also has a marked sedative effect. The presence of adaptogens in tonic prescriptions, together with amino acids, vitamins and metabolites, is indicative of their excellent compatibility in the general enhancement of the effect.

Biologically active compounds and general tonic prescriptions (see Table 3, group III) constituted a special group. A marked effect is obtained with these products when taken for a long time (30 to 60 days). First of all, we evaluated the stimulating effect of panangin, which is prescribed for various cardiovascular diseases. It was found that panangin has a beneficial effect on efficiency, as a mild stimulant without any side-effects (9-12% PWC_{170} and 10-16% IE) when taken for a 2- and 4-week course. Two agents containing amino acids (panangin and glutamic acid) are also compatible in more complex prescriptions. Glutamic acid has good properties with regard to stimulating efficiency (5% PWC_{170}, 33% IE). It is important to note that long-term intake of glutamic acid led, according to our observations, to an overall effect that is inherent in mild anabolics: increased appetite, body weight and metabolism (increased O_2 uptake at rest and exercise).

Table 1. Tested drugs and prescriptions

Product, dosage, frequency of daily intake	Duration of course, days	Number of subj.
CNS stimulants (I)		
Phenamine (0.005 g), q.d.	Once	8
Metamphetamine (0.003 g), q.d.	"	7
Ephedrine (0.025 g g), q.d.	"	6
Strychnine (0.001 g), q.d.	"	6
Ephedrine (0.015 g)+strychnine(0.0005 g), q.d.	"	[illegible]
Sydnocarb(0.01 g), q.d.	"	5
Ephedrine(0.015 g), b.i.d.	14	5
Strychnine(0.0005 g), b.i.d.	14	5
Ephedrine(0.015 g)+strychnine(0.0005 g), b.i.d.	14	6
Sydnocarb(0.01 g), b.i.d.	10	5
Adaptogens (II)		
Eleutherococcus(60-80 drops), t.i.d.	30	7
Saparal(0.05 g), t.i.d.	21	6
Lachnochilus inebrians (5% aqueous infusion)(1 tb), t.i.d.	21	[illegible]
Biologically active agents and tonics (III)		
Anaprilin(0.04 g), t.i.d.	21	6
Glutamic acid(0.5 g), t.i.d.	30	11
Panangin(1 loz.[lozenge]), t.i.d.	14—30	21
Panangin(1 loz.)+glutamic acid(0.5 g), t.i.d.	30	6
Panangin(1 loz.)+potassium orotate(0.5 g), t.i.d.	30	16
Panangin(1 loz.)+glutamic acid(0.5 g)+potassium orotate(0.5 g), t.i.d.	30	5
Panangin(1 loz.)+glutamic acid(0.5 g)+potassium orotate(0.5 g)+saparal(0.1 g), t.i.d.	50—50—50—21	[illegible]
Panangin(1 loz.)+glutamic acid(0.5 g)+eleuterococcus(60-80 drops), t.i.d.	30	3
Panangin(1 loz.)+saparal(0.5 g)+undevit(1 loz.)+phosphrene(0.5 g), t.i.d.	30	3
Panangin(1 loz.) potassium orotate(0.5 g)+saparal (0.1 g)+decamevit(2 loz.)+phosphrene(0.5g),t.i.d.	50	6
Panangin(1 loz.)+glutamic acid(0.5 g)+saparal (0.1 g)+decamevit(2 loz.)+phosphrene(0.5 g),t.i.d.	50	6
Saparal(0.1 g)+decamevit(2 loz.)+phosphrene (0.5 g), t.i.d.	60	5
Prescriptions combining CNS stimulants and anabolics (IV)		
Panangin(1 loz.),t.i.d.+potassium orotate(0.5 g), t.i.d.+ephedrine(0.015 g), b.i.d.	50—50—14	5
Panangin(1 loz.),t.i.d.+potassium orotate(0.5 g), t.i.d.+strychnine(0.0005 g), b.i.d.	30—30—14	5
Glutamic acid(0.5 g),t.i.d.+nerobol(0.005 g),t.i.d.	30	11
Panangin(1 loz.),t.i.d.+nerobol(0.005 g),t.i.d.	45—30	12
Panangin(1 loz) t.i.d.+retabolil(1 mℓ i.m.) q.d.	30	5
Glutamic acid(0.5 g)t.i.d.+nerobol(0.005 g)t.i.d.+sydnocarb(0.01 g)t.i.d.	45—30—14	6
Glutam.acid(0.5 g) t.i.d.+nerobol(0.005 g)t.i.d.+ephedrine(0.015 g)b.i.d.+strychnine(0.0005 g)b.i.d.	45—30—14—14	5
Panagin(1 loz.)t.i.d.+nerobol(0.005 g)t.i.d.+sydnocarb(0.01 g)t.i.d.	45—30—14	5
Panangin(1 loz.)t.i.d.+nerobol(0.005 g)t.i.d.+ephedrine(0.015 g.b.i.d.+strychnine(0.0005 g) b.i.d.	45—30—14—14	5

Note: The tested products were taken in the daytime under the supervision of the physician in charge.

Against the background of glutamic acid, there was increased endurance of the load at the time of maximum pharmacologic action of phenamine, a strong CNS stimulant. However, in our opinion, the increment of IE is somewhat exaggerated in products No 8 and 12 (see Table 3), with regard to absolute values, since the tests were usually begun with these products, some of the subjects had not yet developed skill in breathing under conditions forced ventilation.

Table 2. Ranked table of criteria of efficacy of drugs according to their effect on physical fitness

Parameter--criterion (difference between background and experiment)			Rating of effect (on the basis of deviation from background)	
	Designation	Unit of measurement	significant	considerable
Functional test on bicycle ergometer PWC_{170}				
Physical fitness	ΔPWC_{170}	%	±10	±20
Cardiac power per 500 kg-m/min	ΔN_1	kg-m/beat	±0.25	±0.5
" " " 1000 kg-m/min	ΔN_2	kg-m/beat	±0.5	±1.0
Pulse debit per 10 min rest after 500 kg-m/min	ΔP_{01}	beats/min	±10	±20
Pulse debit per 10 min rest after 1000 kg-m/min	ΔP_{02}	beats/min	±20	±30
Functional test for IE				
Exercise time on bicycle ergometer at 0.765 PWC_{170}	ΔT	%	±10	±20
Mean HR during exercise	ΔP_e	beats/min	±10	±20
Mean HR over 30-min rest after exerc.	ΔP_0	beats/min	±10	±20
O_2 uptake at rest before exercise	VO_{2r}	mℓ/min	±50	±70
Mean O_2 during exercise	VO_{2e}	mℓ/min	±200	±300

Potassium orotate, vitamines and phosphrene were not given separately; for this reason it was not possible to evaluate their effects proper. Nevertheless, we observed some tendency toward additivity of action of these products with prescriptions No 16-20 (see Table 3). The highest ratings for mild and prolonged stimulation were obtained with the prescription that contained panangin, glutamic acid, saparal, decamevit and phosphrene (17% PWC_{170}, 37% IE). A control study made 2 months later confirmed the high features of this mixture.

Group IV (see Table 3) consisted of prescriptions containing anabolic and CNS stimulators, which were taken in combinations and separately. Unlike those in groups II and III, these products did not elicit such homogeneous reactions. The subjects with higher physical conditioning rated the prescriptions better with regard to well-being, and achieved better in the functional tests. Some of the prescriptions were even rated as producing the highest performance. As a result of giving nerobol and intramuscular injections of retabolil, all of the expected effects were observed, with respect to increment of muscule mass and increased basal metabolism. What is very important is that preliminary intake of anabolics and amino

acids for a long period of time, which created a basic reserve of energy potential and increased energy-producing capacity of the body, enhanced the subsequent effects of a course of low doses of CNS stimulators.

We must discuss the results obtained in the tests with anaprilin. Anaprilin was submitted to a general evaluation, since we were concerned with its blocking properties in the presence of tachycardia and arrhythmia occurring on the first days after real or simulated weightlessness (immersion, antiorthostatic hypokinesia). It was established that there was significant slowing of resting HR, with loads tolerable to both tests, but the subjects reported increased fatigability.

In addition to the tests using the bicycle ergometer, we performed the so-called phenamine test, i.e., functional load at the time of maximum pharmacological effect (of single intake) of phenamine, in order to determine endurance of heavy muscular exercise after a course of general fortifying and tonic agents. We demonstrated some rather interesting patterns. In the adaptogen group, a course of eleutherococcus did not alleviate in any way the effect of a strong stimulator, whereas a course of saparal, which does not have high stimulant properties by itself, not only elicited a 13% increment of IE, but preserved the background HR level during exercise and rest, in the "phenamine test." Administration of lagochilus attenuated somewhat the doping effect of phenamine (there was negligible increase of HR during exercise and in the recovery period), and it led to additional general stimulation (6% PWC_{170}, 10% IE) against the background of increased oxygen uptake during exercise.

The systemic tonic prescriptions in group III without amino acids (panangin, glutamic acid), failed to elicit appreciable changes in endurance of heavy muscular activity against the background of a strong CNS stimulator. In view of the assumed special combinability of prescriptions containing amino acids and anabolics, the results of the phenamine test were very important in the case of prescribing CNS stimulants. We observed a significant increase in endurance after courses of panangin+nerobol, glutamic acid+nerobol, due to an increase in energy-producing capacity of the body (increased O_2 uptake during exercise) with complete removal of doping symptoms, according to HR and AP, particularly in the presence of panangin.

Thus, analysis of the experimental data confirmed that the set of two functional tests on a bicycle ergometer (PWC_{170} and IE, which we introduced) is a proper method for assessing physical fitness and the stimulating effects of pharmacological products (with the selected criteria and ranking). The patterns of the experimental functions of O_2 uptake/CO_2 output time, or oxygen pulse, i.e., the "fatigue curves," have a serious physiological basis, and they continue to develop the conceptions previously expounded in studies of "fatigue curves" of animals [19].

From the standpoint of prevention and recovery, in all cases there are no contraindications for adaptogens (eleutherococcus, saparal, lagochilus inebrians). Special attention should be called to lagochilus (in the form of thick extract), which was discovered and studied by Soviet scientists and which, in our estimation, intensifies appreciably tissular respiration, creates reserves of macroergic compounds and has good properties with regard to direct stimulation of efficiency. The marked sedative effect of this product is also quite important.

Table [illegible]. Comparative efficacy of drugs (influence on efficiency of cardiovascular system and metabolism)

Products and prescriptions	Functional tests					
	[illegible]				II	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CNS stimulators (I)						
Ephedrine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Strychnine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ephedrine+strychnine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sydnocarb	[illegible]	[illegible]	[illegible]	[illegible]	— —	[illegible]
Adaptogens (II)						
Eleutherococcus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Saparal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lagochilus inebrians	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Biologically active agents and tonics (III)						
Glutamic acid	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panangin (14 days)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panangin (30 days)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Anaprilin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panangin+glutamic acid	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panangin+potassium orotate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panangin+glutamic acid+potassium orotate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panangin+potassium orotate+glutamic acid+saparal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panangin+glutamic acid+eleutherococcus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	— —
Panangin+saparal+undevit+phosphrene	[illegible]	[illegible]	[illegible]	[illegible]	— —	— —
Panangin+glutamic acid+saparal+decamevit+phosphrene	[illegible]	— —	— —	[illegible]	— —	— —
Panangin+potassium orotate+saparal+decamevit+phosphrene	[illegible]	— —	[illegible]	[illegible]	— —	[illegible]
Saparal+decamevit+phosphrene	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Prescriptions including CNS stimulants and anabolics (IV)						
Panangin+potassium orotate+ephedrine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panangin+potassium orotate+strychnine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Glutamic acid+nerobol	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nerobol	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Glutamic acid+nerobol+ephedrine+strychnine	[illegible]	— —	[illegible]	[illegible]	[illegible]	[illegible]
Glutamic acid+nerobol+sydnocarb	[illegible]	— —	[illegible]	[illegible]	[illegible]	[illegible]
Panangin+nerobol	[illegible]	[illegible]	[illegible]	[illegible]	— —	[illegible]
Panangin+retabolil	[illegible]	[illegible]	[illegible]	[illegible]	— —	[illegible]
Panangin+nerobol+sydnocarb	[illegible]	[illegible]	[illegible]	[illegible]	— —	— —
Panangin+nerobol+ephedrine+strychnine	[illegible]	[illegible]	[illegible]	[illegible]	— —	— —

Note: PWC[illegible] and I are given in two measurements: rank estimate in the numerator and I change, as compared to background, in denominator.

Prescriptions with many components, containing amino acids, metabolites, adaptogens, vitamins and heavy metal compounds (particularly the one with panangin, glutamic acid, potassium orotate, aminalon, decamevit and phosphrene), which have multifaceted effects on energy-producing capacity of the body and trophic function; they have high efficiency-stimulating properties and are particularly beneficial as a means of conditioning the body for heavy, exhausting loads.

Prescriptions containing amino acids (panangin+glutamic acid, 30-60 days), followed by a course (3-4 to 14 days) of a mixture of ephedrine and strychnine in low doses (0.015+0.0005 g/day) had the best efficiency-stimulating properties. Such formulas can improve ["correct"] efficiency with development of processes of profound fatigue and tension [stress] of functional, humoral and integrative systems of the body.

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CHANGES IN ANIMAL REACTIVITY UNDER THE INFLUENCE OF PROLONGED ROTATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 51-54

[Article by N. I. Arlashchenko and A. A. Shipov, submitted 20 Nov 78]

[English abstract from source]

[illegible]

[Text] The study of physiological reactions during and after prolonged rotation is not only of theoretical interest from the standpoint of gravity biology [1, 2], but of practical significance in view of the prospects of long-term stays in space systems with artificial gravity [3].

Our objective here was to study the functions of the vestibular analyzer, state of barrier functions and radioresistance of animals after 2 weeks in a rotating system.

Methods

We conducted this study on 54 chinchilla rabbits of both sexes weighing 3-4 kg. The animals were divided into three equal groups: experimental, synchronous control and vivarium control. The experimental group was submitted to repeated (intermittent) rotation at a constant angular velocity of 7.3 r/min for 22 or 7-8 h* per day on a MVK-2 unit [4] with a 110 cm radius. Overall rotation time constituted 14 days. The animals in the synchronous control were next to the revolving unit under the same upkeep conditions as the experimental group. The vivarium control rabbits were kept under the usual vivarium conditions.

We assessed reactivity of animals after prolonged rotation on the basis of vestibular analyzer function, impairment of barrier function of vessels of the ciliary tract in response to acute irradiation, as well as animal resistance to radiation.

*With the same overall rotation time, a change in duration of some periods of rotation did not have an appreciable influence on the physiological effects [1].

We examined vestibular analyzer function before the experiment (twice) and immediately after the period of rotation, recording the nystagmic reflex of the eyes, which occurs when the receptors of the semicircular canals are stimulated by angular accelerations. We used a VU-2 unit [4] for this examination adhering to the following program: positive acceleration of 2°/s--rotation at set constant rate for 1 min--stop within 2 s (stop stimulus). There was a 2-min interval between successive rotations. Reactivity of the vestibular analyzer was assessed according to the number of nystagmic beats in response to increasing stop stimuli (30, 60, 90 and 120°/s). Nystagmus was recorded by means of an electroencephalograph, for which purpose needle electrodes were introduced in the skin of the lateral canthus.

Radiation in a dosage of 700 R was delivered from an EGO-2 (^{60}Co, dose rate 173 R/min) or Start-1 (^{137}Cs, dose rate 37 R/min) unit. Control animals (8 rabbits) were given intramuscular injections of ethaperazine (1 mg/kg body weight) 15 min before irradiation. Two hours later we assessed the degree of impairment of barrier function of vessels of the ciliary tract. For this purpose, the animals were given intravenous injections of fluorescein (0.4 cc 5% solution/kg body weight), and then we recorded for 3.5 h passage of the dye into the humor of the anterior chamber of the eye by means of a fluorescent microphotometer [5]. Changes in permeability of the vascular-tissular (hemato-ophthalmic) barrier were expressed in units on the scale of a microammeter.

Results and Discussion

In the background studies, we failed to demonstrate reliable differences in the nystagmic reaction of all groups of animals. For this reason, the obtained data are illustrated in Figure 1 (results of first examination) in the form of a single curve. Examination after a period of rotation revealed that the nystagmic reaction of experimental animals was diminished as compared to the reactions of control groups, the differences being reliable for the reactions to stop stimuli of 30 and 60°/s.

The dynamics of changes in permeability of the hemato-ophthalmic barrier 2 h after exposure to ionizing radiation were indicative of less marked impairment of barrier function of eye vessels in rotated animals, as compared to the control groups (Figure 2). The postradiation changes in vascular permeability of animals in the experimental group did not differ from the changes in control animals who were given ethaperazine 15 min before irradiation.

There were no deaths among animals in the experimental group on the 30th postradiation day, whereas mortality constituted 38% in the control groups. The increase in radioresistance of animals in the experimental group was followed by a decrease, which was demonstrated when they were exposed to radiation again, when the death rate in the experimental group rose to 71%, remaining at the same level (38%) in control animals.

It is known that being in a rotating system involves exposure to centripetal accelerations, as well as precession and Coriolis accelerations [3]. The accelerations concomitant with rotation have both a specific (mechanical) and nonspecific, stress-reaction type of effect [2]. The decrease in number of beats, which we observed in the postrotation aftereffect period, was apparently due to the prolonged and combined stimulation of the otolith system by centripetal and Coriolis

accelerations, and that of receptors of the semicircular canals by precession accelerations [6].

Figure 1.
Characteristics of reactivity of vestibular analyzer after prolonged rotation. X-axis, stop stimuli (degrees per s); y-axis, number of nystagmic beats

1) background examination
2, 3) animals of synchronous control and experimental group, respectively, after termination of experiment

Figure 2.
Dynamics of postradiation disturbances in permeability of hemato-ophthalmic barrier

X-axis, time after intravenous injection of fluorescein (min); y-axis, intensity of fluorescence in anterior chamber humor (arbitrary units)

1) vivarium control
2) rotated animals
3) control group given ethaperazine prior to irradiation
4) synchronous control

On the other hand, a vestibular load, like muscle conditioning, hardening [inurement] or the long-term effects of stressors, causes nonspecific increase in body resistance to the most varied environmental factors [7, 8], including radiation [9, 11]. Under our experimental conditions, we also demonstrated increase in the animals' radioresistance. At the same time, it was shown that the increased resistance is transient, since overall mortality remained constant in all groups as a result of two-fold irradiation. We demonstrated the nonspecific nature of influence of factors of prolonged rotation on reactivity on the example of postradiation disturbances in permeability of the hemato-ophthalmic barrier. Indeed, there were similar postradiation changes in permeability of vessels of the ciliary tract (see Figure 2) in animals submitted to rotation and those given ethaperazine, which

causes nonspecific decrease in reactivity to endogenous and exogenous stimuli [12]. Previously, A. G. Kuzovkov observed a reliable decrease in permeability of the brain barrier vessels to fluorescein under the influence of ethaperazine, in acute experiments on rats [13].

Thus, it was established that long-term (up to 14 days) presence of animals in a rotating system (7.5 r/min, radius 110 cm) alters reactivity according to parameters of radioresistance, reactivity of the vestibular analyzer and state of barrier function of optic vessels. This is indicative of increased systemic resistance to physical environmental factors.

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EFFECT OF SIMULATED GRAVITY ON THE CHICK EMBRYO MYOCARDIUM

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 54-57

[Article by S. S. Oganesyan, R. A. Gevorkyan, T. S. Zaminyan and M. A. Eloyan, submitted 21 Aug 79]

[English abstract from source]

[illegible]

[Text] There are data in the literature concerning the effects of space flight factors on some physiological and biochemical parameters of the muscular system during ontogenetic development of animals [1-4]. However, the mechanism of effect of altered gravity field on myocardial myocyte function and the molecular-genetic bases of adaptation thereof to extreme conditions has still not been elucidated.

Methods

The studies were conducted on 390 Leghorn chick embryos. The eggs were incubated in a laboratory incubator at a temperature of 37.5±0.5°C and relative humidity of 55-65%. An altered gravity field was simulated by means of daily centrifuging of the eggs for 20 min from the 5th to 8th day of embryonic development (1st group; 70 control and 80 experimental eggs) and from the 11th to 20th day of development (2d group; 125 control and 115 experimental eggs). For this purpose an attachment was designed for the TsLNR-1 centrifuge, the rotating disk of which was 21.3 cm in diameter and which turned at the rate of 170 r/min, which corresponded to a G force of 7 G. The gravitation vector traversed the eggs in a transverse

direction. The initial weight of the eggs was the same in control and experimental groups, and it constituted 58.8±0.9 g.

We obtained a culture of embryonic myocardial cells according to Cavanaugh [5]. The amplitude and frequency of contraction of cell clusters were recorded using a device we designed, with a shadow sensor. We estimated the degree of myocardial hypertrophy from the cardiac index, as well as micrometry of cells in culture [6]. We performed electrophoretic separation of myofibrillar proteins and subunits thereof on 10% polyacrylamide gel by the method of Katagiri and Morkin [7].

Protein markers and muscle protein preparations purified in our laboratory were used to estimate molecular mass and to identify the bands on electrophoregrams. Cathepsin activity of myofibrillar extracts purified according to Iodice et al. [8] was determined on the basis of dissociation of denatured bovine hemoglobin according to Anson [9]. Protein concentration was determined from nitrogen (micro-Kjeldahl).

Results and Discussion

Survival constituted 72% in the control group and 69.5% in the experimental one. The general condition of hatched chicks was satisfactory in both groups. The experimental group of chicks weighed more (by 9.3%) and heart was significantly larger (by 30%). Thus, on the 21st day of embryo development, the heart of control chicks weighed 173.3±8.9 mg and that of experimental ones 225±7.14 mg; the cardiac index of the control group of chicks constituted 4.65±0.17 and that of the experimental ones 5.66±0.17. The differences between body and heart weight of experimental and control groups of chicks were statistically reliable (P<0.001).

Effect of Ca^{2+} (10^{-4} M) on contractile activity of chick myocytes. White columns--control group, striped--experimental
a, b) increase in amplitude and frequency, respectively, of contraction

The average size of myocardial cells was 3.9-15.7 μm in the control group of chicks and 5.8-23.1 μm in the experimental one. Our data conform with the results of studies of other authors, who reported a significant increase in relative dimensions of the heart and cells with hypertrophy of the chick embryo heart [6]. Consequently, it may be concluded that repeated exposure to a gravity load during the period of embryonic development elicits myocardial hypertrophy.

The study of parameters of contraction of ventricular cells in a culture of embryonic myocardium revealed a significant increase in frequency (by 35.1%) and decrease in amplitude (by 32.5%) of contraction in the 1st group of embryos. Interestingly enough, the change in frequency and amplitude characteristics is observed when the embryos are centrifuged for 3-4 days at the early stage of development (5th-8th day).

Automatic function of pacemaker cells of the atria remained without appreciable change under the same conditions. Perhaps, this is related to earlier differentiation of pacemaker cells. As we know, the time of appearance of the first

spontaneous contractions of ventricular cells in tissue culture is directly related to the age of the embryo [10, 11]. Thus, in our experiments, automatic activity of ventricular cells of 8-9-day-old embryos appeared 4-6 h after the start of cultivation. Hence, brief centrifuging during the period between the 5th and 8th days of development affects formation of the rhythm of automatic contractions of ventricular cells.

Centrifuging also led to decreased efficacy of the effect of Ca^{2+} on embryo myocytes (see Figure). The significant decrease in sensitivity to Ca^{2+} effect on amplitude of contractions is indicative of damage to the system of membrane transport of Ca^{2+} under the influence of brief exposure to an altered gravity field during the period of embryonic development we studied.

Effect of altered gravity field (7 G for 20 min daily) on myofibrillar protein content of myocardium of hatched chicks

Protein fraction	Relative fraction content, %	
	control embryo group	experimental embryo group
Actin	22.2±1.45	11.5±0.25
Troponin-T	14.5±2.3	10.4±0.0
Tropomyosin	3.5±0.75	12.6±0.11
Troponin-I		22.9±0.07
First light myosin chain	14.5±2.3	10.8±0.14
Second light myosin chain Troponin-C	5.3±1.0	2.7±0.07
Third light myosin chain	--	5.0±0.15

Thus, it was demonstrated that when a phasic mode of contraction is imposed on the rabbit's tonic skeletal muscle in situ, the earliest changes are found in Ca--muscle sheath pump function [12], which is apparently due to the high rate of renewal of membrane proteins. We previously demonstrated that a change in mode of heart function leads to impairment of normal quantitative correlation between protein subunits in the myosin macromolecule [13, 14], and it is also associated with significant increase in myofibrillar proteolytic activity [15].

Daily 20-min centrifuging of chick embryos between the 11th and 20th day of development led to reliable ($P<0.001$) increase in cathepsin activity of purified myocardial myofibrils (by 40%) and femoral muscles (by 46%), as compared to the thoracic muscle (by 25%).

Thus, changes are observed in protein catabolism of all types of muscles under the influence of an altered gravity field, and this is apparently attributable to a change in muscle cathepsin activity, particularly cathepsin D, which is involved in catabolic processes of myofibrillar [16] proteins proper.

The changes in protein renewal under the influence of brief exposure to altered gravity were associated with a change in quantitative correlation between myofibrillar proteins in the myocardium. A significant decrease in actin, second

light chain of myosin and troponin-C (Ca^{2+}-binding troponin subunit) was observed in hatched chicks. The quantitative actin/troponin-C ratio did not change: while it constituted 6.1 in the control group, it was 4.2 in the experimental one. Tropomyosin content increased significantly. There was regular appearance of the third light myosin chain; there was no appreciable change in troponin-T content (see Table).

The obtained data are indicative of strong dependence of processes of differentiation and formation of membrane and contractile structures on effects of the gravity field in the course of embryonic development. Evidently, the Ca transport function of membranes and synthesis of Ca^{2+}-binding proteins (troponin-C, light myosin chains) are subject to the earliest changes. The most probable cause of the observed changes could be that the reaction of genetic control of protein synthesis depends on the gravitation factor, on the one hand, and that the activity of proteolytic enzymes involved in synthesis and dissociation of different myofibrillar proteins is highly sensitive to gravity factors, on the other.

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RELATIONSHIP BETWEEN PULSED FILLING OF EARLOBE VESSELS AND CARDIAC EXTRASYSTOLE DURING 'HEAD-PELVIS' ACCELERATIONS AFTER EXPOSURE TO SIMULATED WEIGHTLESSNESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 57-60

[Article by I. F. Vil'-Vil'yams, submitted 10 Apr 79]

[English abstract from source]

[illegible]

[Text] It is known that disturbances of regional circulation in head vessels (vision disorders in the form of "gray" or "black" veil and loss of consciousness) and cardiac arrhythmia [1, 2] are among the causes that limit the body's resistance to "head-pelvis" accelerations. There are isolated reports of a possible correlation between these symptoms [3]. It was also established that there is a decrease in the body's resistance to "head-pelvis" accelerations after simulation of the effects of deconditioning in weightlessness by means of immersion [4]; this is associated with an increase in incidence of ectopic cardiac arrhythmia [5].

Our objective here was to investigate the correlation between disturbances referable to pulsed filling of earlobe vessels with blood and cardiac arrhythmias during prolonged exposure to head-pelvis accelerations following conditions simulating weightlessness.

Methods

We conducted 91 studies involving 18 healthy male volunteers ranging in age from 23 to 36 years, under different conditions: in the usual environment (29 men), after simulation of effects of deconditioning by means of 3-day "dry" immersion (18 men) and after combining immersion with periodic exposure to G forces (+0.8, 1.2 and 1.6 Gz for 40-60 min 2-3 times a day) on a short-arm centrifuge (SAC; 44 men). We created +3 Gz for up to 5 min on a centrifuge with 7.25 m radius, which was used as a functional load test. The gradient of the set of accelerations constituted 0.2 G/s.

During all of the tests, we recorded the EKG in the Neb leads, estimated pulsed [illegible] filling of carotid vessels on photoplethysmograms (PPG) and arterial pressure (AP) in the shoulder region according to Korotkov sounds (for 1 min in the 1st, 3d and 5th min of the "plateau"). In some studies we determined AP in carotid vessels from the PPG.

A decline in amplitude of PPG of carotid vessels to the isoelectric line and development of visual disturbances in the form of "gray" or "black" veil were used as criteria of tolerance of +Gz accelerations.

All of the data were submitted to processing by methods of variation statistics, with calculation of the t criterion of Student and the χ^2 criterion.

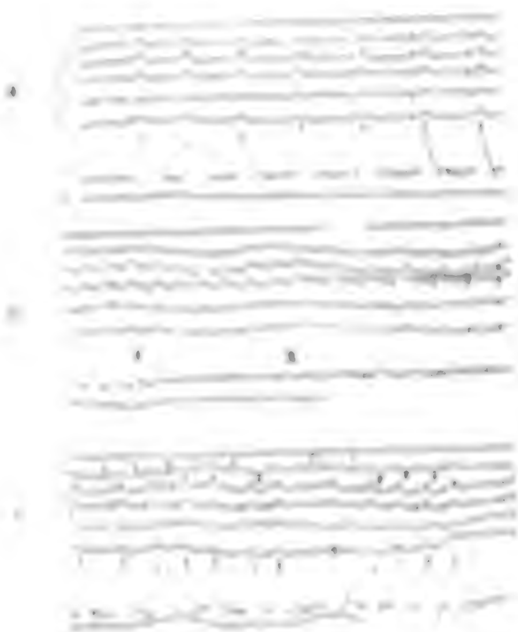
Results and Discussion

Analysis of the dynamics of PPG amplitude of carotid vessels with exposure to +Gz [illegible] revealed two main types of reactions: normosthenic and asthenic. With the normosthenic reaction, the amplitude of PPG of carotid vessels dropped to [illegible] of the base value; the heart rate (HR) constituted a mean of [illegible]/min on the "plateau." We observed shortening of P-Q interval and electrical diastole of the heart, decrease in $R_{II,III}$ waves and increase in $S_{II,III}$ waves. Systolic AP in the region of the shoulder constituted [illegible], diastolic was [illegible] and pulsed [illegible] mm Hg. A normosthenic reaction was observed before immersion, in [illegible] of the cases after "pure" immersion and [illegible] of the cases after immersion and combination thereof with [illegible] on the SAP. With the asthenic reaction, we observed a decrease in PPG amplitude of carotid vessels to the baseline, which was associated with a drop of AP level in carotid vessels to less than 50 mm Hg. The average HR "per plateau" constituted [illegible]/min. The changes in configuration of the EKG did not differ from those described above. In some cases, we also saw a horizontal S-T segment and flattening of T wave in the D lead of Neb. During [illegible], there was gradual decline of systemic AP. Systolic AP in the shoulder region constituted [illegible] on the average over the "plateau," diastolic was [illegible] and pulsed [illegible] mm Hg. As compared to the normosthenic reaction, there was a reliable ($P<0.01$) increase in HR, decline of systolic and pulsed AP in the shoulder region and a tendency ($P<0.1$) toward elevation of diastolic AP.

The asthenic reaction was observed in [illegible] of the cases after "pure" immersion and [illegible] after combining immersion with rotation on the SAP.

With both types of reactions, [illegible] arrhythmia was the predominant form of disturbance of cardiac rhythm. In some cases, there was also [illegible] and migration of the rhythm source over the sinus node (see Figure).

Analysis of the correlation between changes in pulsed filling of carotid vessels and [illegible] arrhythmia revealed that there was a reliable increase in number of cases (the χ^2 criterion equaled [illegible], $P<0.05$) with [illegible] arrhythmia with development of disturbances of regional circulation in head vessels of the asthenic type, as compared to the normosthenic reaction. As a rule, an increase in number of extrasystoles was demonstrated during the period of stopping the centrifuge and in the first [illegible] min of the recovery period after it stopped. The [illegible] there was also an increase in number of [illegible] forms of [illegible] (see Table) [illegible].



Example of dynamics of cardiovascular system parameters with +3 Gz

a) background

b) 3 G plateau, 210 s

Arrow shows time of decrease in amplitude of PPG of earlobe vessels to base-line. X shows the start of development of relative bradycardia.

c) slowing down of centrifuge, 30th s

Migration of rhythm source over sinus node. The P's indicate direction of the P wave in the D lead of Neb.

Correlation between regional circulatory disturbances in vessels of the head and ectopic cardiac arrythmia during exposure to +3 Gz accelerations up to 3 min after "dry" immersion

Reaction of PPG amplitude of earlobe vessels	Number of cases		Extrasystoles			
			number		form	
	total	with extra-systoles	total	average per arrythmia case	single	group & systemic
Ischemic	24	16	98	6.1	71	27
Normotonic	67	26	84	3.2	72	12
totals	91	42	182	4.3	143	39

A comparison of regional AP in earlobe vessels to systemic AP and incidence of development of extrasystolic arrhythmia revealed that there was an effect of dissociation between regional and systemic AP levels in some cases, where extrasystolia coincided with the time of recording the pressure. The AP of earlobe vessels dropped appreciably, whereas systemic AP still remained on a rather high level. Under these conditions, the extrasystoles could not have been attributed to difficulty of cardiac output due to high aortic pressure with diminished filling of the heart [8].

However, one should apparently not exaggerate the significance of this factor in the genesis of ectopic arrhythmias, since the most serious forms of arrhythmia observed in our cases, as can be seen in the figure, were noted during slowing of the centrifuge and in the recovery period.

On the basis of data in the literature, it can be assumed that the changes in bioelectrical activity of the myocardium with exposure to "head-pelvis" accelerations

occurred in our subjects as a result of the complex effects of a number of factors: shifting of the heart in the chest under the influence of inertia, fluctuation of tonus of extracardiac nerves and filling of heart chambers with blood, myocardial hypoxia, changes in electrolyte balance, and others [7-9]. The findings revealed that the regional circulatory disturbances in head vessels with long-term exposure to +Gz accelerations after simulated weightlessness were also contributing factors in breakdown of regulatory mechanisms of heart rhythm. Evidently, a rather important part was also played by changes in functional state of the receptor system of the heart and great vessels (in particular, the carotid sinus and aortic arch) under the influence of circulatory hypoxia. That such a mechanism could exist is indicated by predominant occurrence of prognostically significant forms of extrasystolic arrhythmia during braking of the SAC and in the aftereffect period, when the marked rush of blood to the heart caused stimulation of mechanoreceptors of vascular reflexogenic regions.

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EXTERNAL RESPIRATION IN THE PRESENCE OF HYPERBARIC OXYGENATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 80-84

[Article by V. A. Glazkova and I. N. Chernyakov, submitted 4 Jan 79]

[English abstract from source]

[illegible]

[Text] At the present time the method of hyperbaric oxygenation (HBO) is used extensively to cure various hypoxic states. However, external respiration under such conditions has not been sufficiently studied [1, 2].

We shall discuss here the dynamics of parameters of external respiration and acid-base balance (ABB) in man [illegible] related to different HBO modes that are effective in curing altitude [illegible].

These studies were conducted on essentially healthy males 19-28 years of age, in an RKM-1 recompression chamber. Pressure (of up to 3 ata [atm(abs.)]) was created in the chamber by delivering air from tanks. The subjects sat in the chamber in specially adapted armchairs with headrests, which provided more comfortable conditions for staying and working in the chamber, and facilitated recording physiological functions. They breathed with oxygen through a mask from an oxygen set. Throughout the period of the tests, we maintained constant two-way radio communication with the subjects over an intercom system; visual observation of their appearance and behavior was performed through portholes. The pneumogram was recorded using a carbon sensor connected [illegible] a bridge system. Before and after HBO sessions we made a comprehensive st[illegible] static and dynamic lung volumes, mechanics of respiration (pneumotacho[illegible]ic method), perfusion-ventilation ratios in the lungs, acid-base status of blood [illegible]-Astrup method), hematocrit and pO_2 level in capillary blood.

We conducted three series of studies. In all series, the maximum pressure was 3 ata. Oxygen breathing lasted 90 min. Compression and decompression were performed while breathing with oxygen, compression time constituting 10 min and decompression to 1 ata (end of experiment) 16 min. Compression and decompression time was included in overall duration of the study (Table 1).

Table 1. Scope and nature of tests

Study series	Number of subjects	Number of tests	High pressure breathing (min): 3 ata, oxygen (20 min)	3 ata, air (10 min)	2 ata, oxygen (30 min)	2 ata, air (10 min)	Total time of exposure to hyperbaric cond.
I	11	16	60	—	—	—	90
II	8	10	120	30	—	—	180
III	7	9	70	30	170	60	360

Note: Compression of 1 to 3 ata lasted 20 min, decompression from 3 to 2 ata took 5 min and from 2 to 1 ata 5 min while breathing with oxygen.

Eleven men participated in the first series. We conducted 16 tests. The subjects' general condition was quite satisfactory during and after the tests. They presented no complaints and the entire program was fulfilled.

There was a statistically significant increase ($P<0.001$) in voluntary apnea: from 37 s at the start of the study to 42-58 s at the end. The increased duration of apnea with HBO is indicative of diminished sensitivity of the respiratory center to CO_2 under the influence of hyperoxia [3, 4]. At the same time, these findings indicate that there is apparently no decline of man's volitional qualities under the influence of 90 min of hyperbaric hyperoxia. In view of methodological difficulties, most parameters of external respiration were recorded only before and after HBO. Only the rate of respiratory excursions was recorded throughout the test. We demonstrated a reliable slowing of respiration by 2-3 cycles/min.

Tables 2-3 list the summary data illustrating the dynamics of different parameters of external respiration.

Tables 2-3 indicate that no statistically significant deviations of the studied parameters of static and dynamic lung volume, mechanics of respiration and perfusion/ventilation ratios of the lungs were demonstrable after breathing with oxygen under pressure of up to 3 ata for 90 min. This means that under these conditions there was no impairment of pulmonary exchange of gases. Consequently, such functions as ventilation and perfusion of blood in the lungs, as well as diffusion capacity, undergo changes within the range of physiological fluctuations.

With regard to data characterizing the main parameters of external respiration with HBO, it was interesting to track the changes in blood ABB, which reflects homeostasis of the entire body. Blood was taken from a finger and analyzed by the method of Astrup-Siggaard-Andersen before and immediately after the tests.

The obtained data indicate that breathing with oxygen for 90 min in the tested mode leads to a reliable change only in arterial blood pO_2. This parameter reached high [illegible] mm Hg, versus the base level of [illegible] 20-30 min after the HBO session. ABB indices of blood: pH, pCO_2 and TCO_2, buffer bases—BB—levels, standard and actual bicarbonates—SB and AB, as well as hematocrit, were in the range of base values after the HBO session. There was only some tendency toward

increase in acid metabolic products, and BE [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]. Perhaps, these changes reflected primary disorders of cellular metabolism under the influence of hyperbaric [illegible]. As for most of the other ABR parameters, their dynamics indicated preservation of [illegible] homeostasis and transport function of blood (in particular, hemoglobin) with regard to [illegible].

Table [illegible]. Dynamics of external respiration parameters during [illegible] according to spirometry data; M±m

Parameter	Before [illegible]	After [illegible]
Respiration rate, per min	[illegible]	[illegible]
Respiratory volume, ml (tidal volume)	[illegible]	[illegible]
Minute respiratory volume, l/min	[illegible]	[illegible]
Inspiratory reserve volume, ml	[illegible]	[illegible]
Expiratory reserve volume, ml	[illegible]	[illegible]
Minute [illegible] ventilation, l/min	[illegible]	[illegible]
Vital capacity, ml	[illegible]	[illegible]
Functional residual capacity, ml	[illegible]	[illegible]
Residual volume, ml	[illegible]	[illegible]
Forced expiratory volume per s, ml	[illegible]	[illegible]
Forced expiratory volume per s/vital capacity, %	[illegible]	[illegible]
Anatomic dead space, ml	[illegible]	[illegible]
Physiological dead space, ml	[illegible]	[illegible]
Alveolar dead space, ml	[illegible]	[illegible]
Alveolar volume, ml	[illegible]	[illegible]
Nonperfused alveoli, %	[illegible]	[illegible]
[illegible], ml	[illegible]	[illegible]
Effective pulmonary ventilation, %	[illegible]	[illegible]

All of the foregoing indicates that the tested [illegible] conditions elicited some changes in man with regard to condition of the main parameters of external respiration and ABR. The direction and severity of these changes were in the range of physiological fluctuations, and they reflected triggering of the body's defense reactions to hyperoxia. The most marked changes were increased duration of voluntary apnea, reduced rate of respiration and tendency toward build-up of acid metabolic products in blood.

The objective of the second series was to determine the dynamics of parameters of external respiration with oxygen exposure [illegible] min. For this purpose, the subject switched periodically, [illegible] 20 min, from breathing with oxygen to air, with retention of high pressure in the chamber ([illegible]). Air breathing time was [illegible] min, after which there was a switch to oxygen breathing, etc. There were [illegible] [illegible]. Each consisted of 20 min of oxygen and 10 min of air breathing. The [illegible] lasted a total of [illegible] min, including oxygen breathing for [illegible] min.

The studies were conducted on 8 men. They completed the entire program. There were no [illegible] of oxygen toxicity. We recorded the parameters of external respiration before and after the test.

Table 3. Dynamics of parameters of external respiration with HBO, according to pneumotachographic data, M±m

Parameter	Before HBO	AFTER HBO
t_i, s	[illegible]	[illegible]
t_e, s	[illegible]	[illegible]
t_i/t_e	[illegible]	[illegible]
Vi_{max}, l/s	[illegible]	[illegible]
Ve_{max}, l/s	[illegible]	[illegible]
t_{Vi}, s	[illegible]	[illegible]
t_{Ve}, s	[illegible]	[illegible]
Vi_m, l/s	[illegible]	[illegible]
Ve_m, l/s	[illegible]	[illegible]

Note: n = [illegible].

Key:
t_i) total inspiration time — t_{Vi}) time of maximum inspiration
t_e) total expiration time — t_{Ve}) time of maximum expiration
Vi_{max}) maximum inspiration volume — Vi_m) mean inspiratory volume
Ve_{max}) maximum expiration volume — Ve_m) mean expiratory volume

Analysis of the obtained data shows that the noticeable changes were a decline of tidal volume from [illegible] to [illegible] ml, vital capacity from [illegible] to [illegible] ml, forced expiratory volume per second from [illegible] to [illegible] ml, increase in residual volume from [illegible] to [illegible] ml. These changes were within the range of reading error. In addition the stability of other parameters was indicative of absence of any pathology referable to respiration.

The same direction of changes in percentage of unperfused alveoli (from [illegible] to [illegible]) and alveolar-arterial carbon dioxide gradient (from [illegible] to [illegible] mm Hg) merits attention. Such dynamics of perfusion-ventilation relations illustrates the triggering of defense mechanisms on the level of the lungs. Analysis of parameters of ABB of blood failed to demonstrate any appreciable deviations from the base values. Nor did we observe an increase in acid metabolic products (BE [illegible], BB [illegible], SB [illegible] meq/l). Consequently, acid-base homeostasis was not impaired with the HBO mode we tested.

In the third series of tests, we studied external respiration with further extension of the HBO sessions. Development of longer HBO sessions was needed to treat the more severe symptoms of caisson disease. The protocol of the test was as follows. For the first 2 h the subject was in the chamber at a pressure of 3 atm and breathed with oxygen (20 min) with periodic switching to air (10 min). Then pressure was dropped to 2 atm in the chamber, and under these conditions the subject breathed with oxygen for [illegible] h, for 20 min at a time, with 10-min changes to air. The test lasted a total of [illegible] min ([illegible] h), with [illegible] min spent on breathing with oxygen at pressure of 3 and 2 atm. A total of [illegible] tests on [illegible] subjects were performed.

The results of this series of experiments were analogous to those of the preceding ones. The program was completed in its entirety. There were no signs of oxygen

[illegible]. The changes in the parameters studied were in the range of physiological reactions. There was reliable and significant increase only in duration of apnea, from [illegible] s when breathing with oxygen at the start of the test to 80-98 s at the end. A comparison of static and dynamic lung volumes before and after the HBO session failed to demonstrate marked deviations of the external respiration parameters that we studied.

The results of these studies enable us to conclude that the changes in one of the important body functions, external respiration, are within the range of normal deviations in man, and this confirms the feasibility of using the tested modes of hyperbaric oxygenation in the interests of aerospace medicine.

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RESPIRATORY REACTIONS TO CHANGES IN GAS ENVIRONMENT DENSITY AT DIFFERENT RATES OF INSPIRATORY FLOW

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 61-64

[Article by I. S. Breslav, Ye. L. Kalacheva, L. A. Konza and N. I. Klyueva, submitted 20 Jun 79]

[English abstract from source]

[illegible]

[Text] Respiratory mixtures differing in density are used during deep-water dives and occasionally in aerospace medical practice. During calm breathing, even a significant increase in gas density does not have an appreciable physiological effect. However, with acceleration of gas flow in the bronchotracheal tree, there is a rapid increase in nonelastic resistance to respiration as a function of gas density, in accordance with the well-known equation of Rohrer. The increasing resistance limits the functional reserve of the ventilation system. In the case of forced breathing due to a physical load and/or development of hypercapnia, this factor could have an adverse effect on the body and efficiency [fitness] [1-3]. This makes it necessary to have comprehensive knowledge of the effect of altered environment density on respiratory function as a function of rates of gas flow, as well as to take it into consideration.

In this work, we have tried to evaluate such functions while having man breathe with gas mixtures differing in density, and to make a physiological analysis of animal reactions to inhalation of such mixtures during calm and forced breathing.

Methods

We used air and oxygen mixtures where N_2 was replaced with He or SF_6. The estimated density of the He-O_2 mixture is 0.34 in relation to air and that of the SF_6-O_2

[illegible]. The rate of gas flow in the airway was changed in man by voluntary change in rhythm and depth of respiration and in animals by means of [illegible]. In addition, we determined the effect of gas mixture density on functional reserves of the human respiratory system according to maximum voluntary ventilation.

We conducted this study on [illegible] healthy young men, as well as [illegible] anesthetized [illegible]. We used the spirographic method to record the following: tidal volume (V_T), pulmonary ventilation ($\dot{V}$) and inspiratory flow rate (V_i). Using a two-coordinate recorder [illegible], we recorded intrathoracic pressure (through an esophageal probe) and tidal volume (from the spirograph), and we plotted the volume-pressure (respiratory loop) diagram, processing of which enabled us to calculate the work of the respiratory system and energy cost per liter ventilation ($W/\dot{V}$). In cats, we also recorded the electrical activity of the phrenic nerve (EA) by a method previously described [illegible]. We delivered a mixture of [illegible] with [illegible], He or SF_6 for respiration. In some of the experiments on cats, we added [illegible] to these mixtures. During the test, the men breathed in either a free or specified mode of frequency and depth, which were maintained by means of a special device [illegible]. We describe below the statistically significant and [illegible] changes in the parameters studied that were caused by using [illegible] and [illegible] SF_6-O_2 mixtures, as compared to the control (N_2-O_2) mixture.

Results and Discussion

Under free breathing conditions, the subjects adjusted to gas mixtures of unusual density by changing the pattern of pulmonary ventilation. When inhaling [illegible], respiration became faster due to shortening of inspiration and expiration, and there was a decrease in tidal volume. The SF_6-O_2 mixture elicited the opposite changes. These mixtures did not cause appreciable changes in parameters of respiratory biomechanics and, consequently, energy cost of pulmonary ventilation.

[illegible] changes in biomechanics of respiration when inhaling different mixtures [illegible] voluntary increase in pulmonary ventilation.

[illegible] voluntary ventilation was increased by breathing [illegible], inspiratory flow rate [illegible], as compared to control (Figure 1).

[illegible] breathing [illegible] there was some decrease in work performed for [illegible] ventilation, as compared to breathing [illegible] air. [illegible] SF_6 [illegible] energy cost of pulmonary ventilation.

[illegible] values of maximum voluntary ventilation (MVV) [illegible] (Figure 2) [illegible].

[illegible] range of [illegible] decrease [illegible] voluntary ventilation. However, [illegible] breathing, when the rate of gas flow in the airways [illegible].

Figure 1.
Effect of altered density of gas mixture on energy cost of human respiratory function. X-axis, peak $\dot{V}_i$ (l/s); y-axis, W_T/V_T (kg-m/l)

Effect of altered density of gas mixture on MPV (l/min) in man. The horizontal lines near the bottom of the columns refer to $\dot{V}$ at rest

Key to Figures 1, 2 and 3:
1) air 2) $He-O_2$ 3) SF_6-O_2

The changes in density of gas mixtures had no effect on pulmonary ventilation or rate of inspiratory flow in calmly breathing cats (Figure 3a). However, there was compensation of additional resistance created by inhalation of SF_6-O_2 mixture by means of increased exertion developed by respiratory muscles, as indicated by the increase in W_T/V_T. On the basis of increase in APN, it may be concluded that there was intensification of inspiratory activity of the respiratory center. $pACO_2$ was elevated. There was no difference from the control in $\dot{V}$ during breathing with the SF_6-O_2 mixture. It is possible that the high density of the respiratory mixture influences the composition of different fractions of exhaled gas, due to changes in intrapulmonary distribution of CO_2 and/or respiratory pattern.

Figure 3.
Changes in the cat's respiratory parameters with inhalation of mixtures of different density under normocapnic (a) and hypercapnic (b) conditions.

Parameters(top to bottom): $\dot{V}$, $\dot{V}_i$, W_T/V_T, APN (% of level in air) and $pACO_2$ (mm Hg).

*Changes in parameter are reliable, as compared to level in air (P<0.05).

While inhalation of $He-O_2$ during calm breathing did not elicit significant changes in the parameters under study, in the case of hypercapnia due to addition of CO_2 to the inhaled mixtures (Figure 3b), the decreased density of the gas environment was manifested both in an increase in ventilation and decline of APN. Breathing

with a mixture of Ar-O2 was associated with the opposite changes. In this case, we were impressed by the significant increase in energy cost of pulmonary ventilation. There was a substantial elevation of [illegible] parameter, as compared to breathing with an N_2-O_2 mixture, and this can be evaluated as the result of intensification of ventilating reaction to hypercapnia in view of the increased resistance to breathing.

Thus, a high density breathing mixture elicited an increase in energy expended by rats for the function of the ventilation system even with calm breathing. The effect of diminished density of the respiratory mixture was manifested only in the case of forced breathing (hypercapnia), and this was manifested only by a decrease in [illegible] activity of the respiratory system.

Our data confirm that the "alleviating" effect of He mixtures could have practical application only when there is intensification of respiratory function: increased resistance to respiration, hypercapnia and muscular activity (5,8).

The absence of significant changes in pulmonary ventilation while breathing with a "heavy" gas mixture is not indicative of absence of reactions by the respiratory system. On the contrary, these reactions, i.e., "discrete" increase in respiratory activity [illegible] diminished ventilation reserves—are quite interesting in the light of the problems of submarine medicine. A normoxic SF_6-O_2 mixture is equivalent in density to the air inhaled by a diver at a depth of [illegible] m, or a mixture of He-O_2 at a depth close to 300 m water (pressure of 30 kgf/cm²). It was demonstrated on rabbits that prolonged breathing with such a mixture elicited signs of impaired CO_2 transport [9]. Thus, one must take into consideration the low endurance of [illegible] resistance of the respiratory system of these animals [10].

In man, who has a relatively larger ventilation reserve, breathing difficulties were themselves known when the gas environment increases in density at specific flow rates in the airways. Some researchers observed retention of CO_2 associated with signs of respiratory insufficiency in working divers when the density of inhaled mixtures was increased by 6-7 times [3, 11]. Indeed, judging from the above-cited MVV, with such density of the gas environment man can perform work not exceeding 100 W, and with this load the "working" ventilation will reach the maximum possible level under these conditions. With higher densities, performance of strenuous work will generally be impossible, and this has been confirmed in practice [12, 13].

The exact figure of maximum density (pressure, depth) for different work loads has not yet been established. Nor do we have a clear idea about the factor that limits [illegible]: whether it is a load that the respiratory muscles cannot [illegible] or impairment of CO_2 transport (and, perhaps, that of oxygen) in the organism. Future studies should answer these important questions.

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UDC: 612.275.1

ON TOXIC EFFECT OF INSIGNIFICANT OXYGEN EXCESS IN AN ARTIFICIAL GAS ATMOSPHERE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 67-[illegible]

[Article by V. M. Gramenitskiy*, V. B. Malkin, L. K. Romanova, Ye. V. Loginova, S. A. Andronova and N. A. Turova, submitted 4 Aug 80]

(English abstract from source)

[illegible]

[Text] The question of life support for cosmonauts during long-term flights is related to the creation of an artificial gas atmosphere (AGA) in the spacecraft cabin. This question has not yet been unequivocally settled in the works of different authors who investigated the possibility of using different AGA variants [1, 2]. When discussing the possibility of using AGA with elevated O_2 content, attention is usually concentrated on two questions: 1) determination of maximum permissible O_2 concentration in AGA, i.e., range of toxic effect of the hyperoxic atmosphere, and 2) investigation of the body's adaptation to high concentrations of O_2. Both questions have important practical implications, and they have ceased to be the subject of purely theoretical research, since a single-gas hyperoxic AGA with pO_2 = 258 mm Hg had already been used in the American Gemini and Apollo spacecraft. The use of such AGA in flight was preceded by experimental studies, most of which failed to demonstrate morphological or functional changes in animals during a prolonged stay in a moderately (pO_2 = 258 mm Hg) hyperoxic environment [1-3].

However, some American authors [3] observed manifestation of the toxic effect of O_2 (changes in structure of the hepatic mitochondria) in animals following long-term (up to 8-9 months) exposure to AGA with pO_2 raised to 258 mm Hg. In one of the studies with man, the subjects also developed discomfort in a single-gas AGA with pO_2 = 258-260 mm Hg [4]. Some subjects complained of retrosternal pain, they developed atelectasis of the lungs. The findings of these studies were not corroborated by those of Soviet authors.

*Deceased.

Equally contradictory were data cited in the literature with regard to possible adaptation of the organism to high pO_2 in an AGA [1-3].

In view of the foregoing, we undertook a study whose objective was to assess the effect on animals of long-term exposure to moderately elevated concentrations of O_2, which many researchers consider to be physiologically permissible [1, 2]. It was deemed important to determine whether exposure to such an AGA was associated with any adaptive changes altering animal resistance to subsequent hyperoxia.

Methods

Experiments were conducted in a pressure chamber, with overall barometric pressure of 713±7 mm Hg, and temperature in the chamber was held at 21-23°C; relative humidity constituted a mean of 75% (67-82%), while CO_2 content did not exceed permissible levels (1%). The O_2 concentration in the chamber ranged from 32.6 to 35% throughout the experiment. The experiment lasted 24 days. We used 138 albino Wistar rats and 171 $C_{57}BL$ mice. The animals were divided into two groups: control and experimental. The control group was kept under the same conditions as the experimental one, but at normal partial oxygen pressure. We assayed hemoglobin and erythrocytes of peripheral blood and O_2 uptake in all animals; they were weighed and temperature taken regularly.

After termination of the experiments, the rat lungs were submitted to light optic and electron microscopic examination.* Upon termination of the experiment, the experimental mice were exposed to elevated O_2 pressure (4 atm) for 30-60 min in order to demonstrate either an adaptive effect or latent lesions due to the prolonged stay in the moderately hyperoxic atmosphere.

Results and Discussion

Presence in a hyperoxic gas atmosphere for 24 days was not associated with any appreciable changes in the animals' main physiological parameters. O_2 uptake, body temperature, peripheral blood hemoglobin and erythrocyte content, and body weight of experimental and control animals failed to demonstrate any significant differences. The behavior and appearance of experimental animals also failed to differ from the control.

Morphological examination of the lungs revealed that the animals reacted differently to 24-day exposure to hyperoxic AGA with pO_2 = 250 mm Hg. The respiratory branch of the lungs appeared the same as in the control in 3 out of 7 experimental rats used for morphological studies; against the background of areas with well-expanded alveoli, there were isolated small areas of dys- and atelectases. However, in the other experimental rats, there was prevalence of areas of dystelectases in the lungs, with an increased number of areas with completely collapsed alveoli (Figure 1). The interalveolar septa were slightly thickened as a result of increased filling of capillaries, and erythrocytes and blood plasma were present in the lumen of some alveoli. The epithelial lining of the airway mucosa showed no changes, and there was no dystrophy of bronchial epithelial cells.

*Electron microscopy and light optic examination of the lungs was performed by L. K. Romanova (Institute of Human Morphology, USSR Academy of Medical Sciences; director: Prof A. P. Avtsyn, academician of the USSR Academy of Medical Sciences).

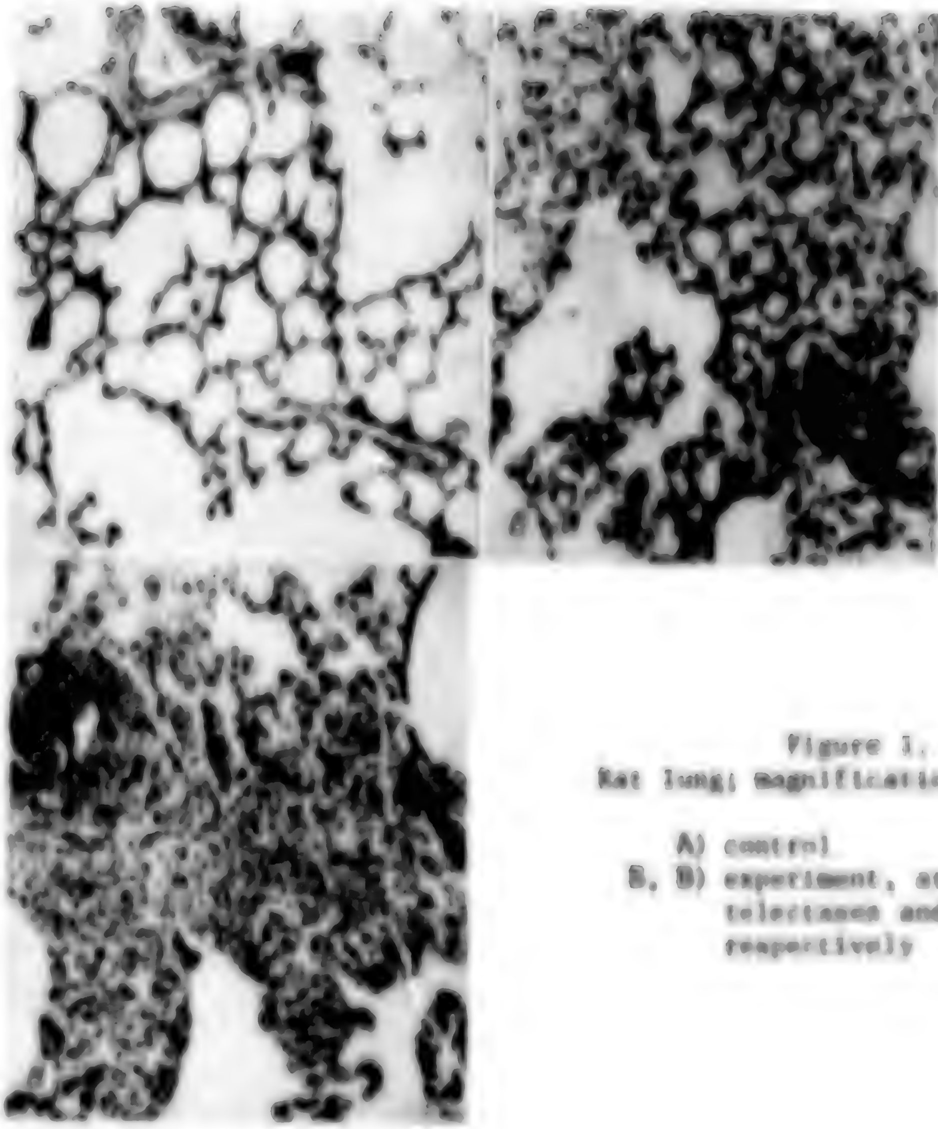

Figure 1.
Rat lung; magnification 120×

A) control
B, B) experiment, areas of dys-
telectases and atelectases,
respectively

Concurrent light optic and electron microscopic examination of the lungs revealed a number of changes in their surfactant system, which plays a large part in biomechanics of respiration [5-7].

Disorganized membranous elements of mature surfactant were visible in the lumen of many alveoli, which was indicative of breakdown and dissociation ["discomplexation"] thereof(Figure 2). In addition, we observed increased secretion of immature surfactant, which was seen in the alveolar lumen in the form of osmiophilic, laminar bodies and membranes. Activation of surfactant secretion was associated

with functional tension of type II alveolocytes, which are responsible for synthesis of surfactant material [7, 8]. Morphometric examination (measurement of area of 100 type II alveolocytes) revealed reliable hypertrophy of these cells in the group of experimental animals. Type II hypertrophied alveolocytes contained an increased amount of osmiophilic bodies, which was indicative of intensive synthesis of surfactant phospholipids in these cells. There were virtually no mitoses in type II alveolocytes of experimental animals. If we consider that, under normal conditions, 87% of the mitoses in the epithelium of the respiratory part of the lung is referable to these cells and expressly they begin to proliferate actively during repair growth [3], we can conclude that the increased functional load due to prolonged inhalation of a mixture with insignificant O_2 excess is involved in depressing the reproductive function of these cells. We failed to demonstrate massive dystrophy of type II alveolocytes or migration thereof in the alveolar lumen.

The alveolar macrophages, which are involved in utilization of surfactant excess [7, 9], were in a state of hyperfunction in the lungs of experimental rats: there was a large amount of osmiophilic laminar inclusions and lysosomes in their cytoplasm.

The above-mentioned changes in the surfactant system of the lungs of experimental animals, which is responsible for surface tension of alveoli, were apparently related to two mutually determined phenomena: in the first place, increased oxidation of surfactant lipids (phospholipids) by inhaled oxygen, i.e., the direct effect of oxygen on surfactant [7, 8, 10, 11] and appearance of a shortage of surfactants on the alveolar surface, which is associated with development of dystelectases and atelectases; in the second place, inadequate adaptation of the lung's surfactant system to the hyperoxic gas atmosphere, which leads to impaired replenishment of surfactant.

Another distinction of the lungs of most experimental animals was the presence of changes in the endothelium of capillaries of the aerohematic barrier. While there was relative integrity of ultrastructure of type I alveolocytes, which are involved in forming the most active zones of the aerohematic barrier, the endothelium presented increased plication of cytoplasmic processes, cytoplasmic edema, impairment of cellular contacts and signs of microclasmatosis. All this is indicative of increased permeability of the endothelium of the pulmonary capillaries. Thus, like in the case of inhalation of gas mixtures with high O_2 concentrations [12], under our experimental conditions we demonstrated differences in sensitivity of cellular elements of the lung to the toxic effect of O_2. The endothelial cells of the aerohematic barrier are a sort of target cells for O_2. However, the mechanism of deleterious effect of O_2 on the endothelium is still unclear.

It must also be noted that there was tension of the immunogenetic system of experimental animals; we often encountered perivascular lymphoid infiltrates in the lungs, in the form of muffs, and there was a rather large amount of lymphocytes and plasma cells in the interstitial space of the interalveolar septa.

Functional tests during brief exposure to high concentrations of O_2 at high pressure (up to 4 atm) were conducted on 61 control mice and 70 experimental ones that had been exposed to 24-day moderate hyperoxia. The tests were performed in a compression chamber that was filled with pure O_2 at a pressure of 4 atm. Exposure time per test (for 13 control and 13 experimental animals) was 60 min, and in other cases it was 30 min.

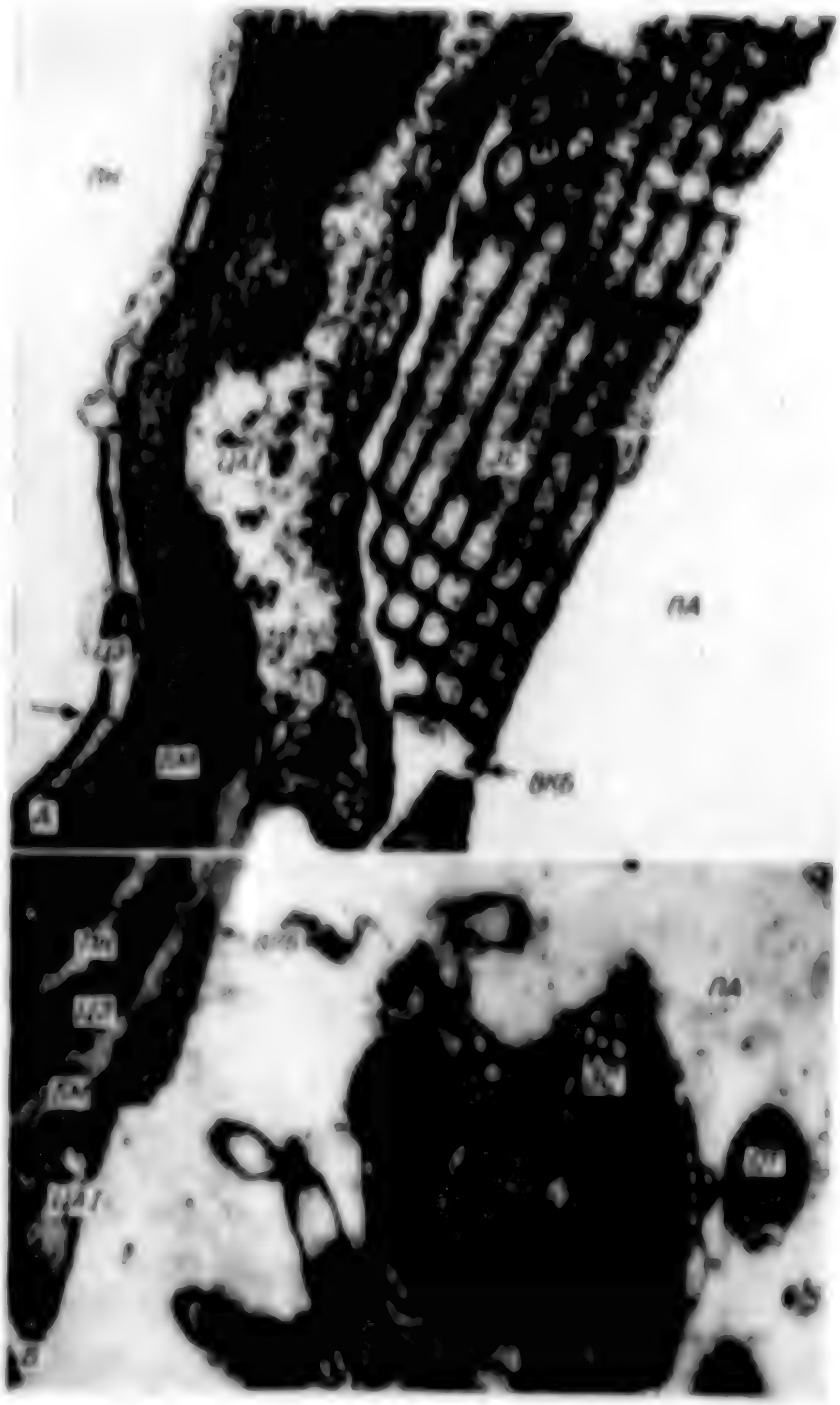

Figure 2. Rat lung

A) control; intact surfactant alveolar complex; magnification 135,000×

B) experiment; traces of destruction of alveolar surfactant complex; membranes of mature surfactant and osmiophilic laminar corpuscles (immature surfactant) in disarray in the alveolar lumen; magnification 75,000×

Key furnished on the next page.

Key to Figure 2:

ПА) alveolar lumen
ПК) capillary lumen
ЗС) mature surfactant membranes situated both directly on the boundary of air-fluid phases and in alveolar lumen (experiment)
ЦА1) type I alveolocyte cytoplasm
ЦЭ) endothelial cytoplasm of pulmonary capillaries
БМ) basement membrane
АКБ) air-blood barrier (arrows)
ОТ) osmiophilic corpuscles (immature form of surfactant)

Exposure of animals for 60 min occurred on the day of termination of the 24-day experiment. All of the experimental and control animals (15 mice in each group) died. In the tests with 30-min exposure, we demonstrated a substantial difference between survival rate of experimental and control mice. All 26 animals of the control group survived. Of the 55 mice in the experimental group exposed to the same conditions, 19 died. The death rate was related to time at which the test was performed. When the hyperbaric test was on the day of termination of the 24-day experiment, 10 out of 15 animals died, 7 out of 15 died after 1 day. One out of 10 animals died on the 3d day and 1 out of 15 on the 10th.

The lungs of the mice that died differed visually from the control: against the background of air-bearing parenchyma, there were large airless regions of a dark cherry color. Upon section, lung tissue produced pinkish foamy fluid, which was indicative of pulmonary edema. The plethoric areas, and occasionally the entire lung were deprived of buoyancy. The pathological changes (edema, hemorrhages) in the lungs were so significant that they could be viewed as the immediate cause of death.

Thus, the experiments revealed that prolonged exposure to moderate hyperoxia with pO_2 of 230 mm Hg lowers animal resistance to the toxic effect of high O_2 pressures. This effect was the most marked on the first days after termination of exposure to a moderately hyperoxic atmosphere and it virtually disappeared as time passed (by the 10th day).

All of the foregoing leads us to a theoretically and practically important thesis, that even a relatively insignificant elevation of partial O_2 pressure in an AGA is undesirable, in the case of long-term exposure. In the literature of recent years there are indications that the threshold of toxic O_2 concentrations is being shifted down more and more. Our study signifies another step in this direction: it shows that even the elevated O_2 concentrations in AGA that have already been used in space flights over long periods of time are not indifferent to the respiratory system. Perhaps, further work on this problem will demonstrate that any degree of elevation above the normal level of O_2 in AGA is undesirable for long-time exposure, constituting many months.

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UDC: 629.78:612.55

RESULTS OF 'HEAT TRANSFER 1' EXPERIMENT CONDUCTED ABOARD THE COSMOS-936 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 73-76

[Article by L. Novak, L. Prokopova (CSSR), A. M. Genin and V. K. Golov (USSR), submitted 30 Nov 79]

[English abstract from source]

The experiment "Heat Exchange 1" has confirmed the hypothesis about weightless[illegible] significant decrease of heat emission from a heated body into the environment [illegible] body surface below 1 m/sec.

[Text] Several works have dealt with questions of setting standards for the microclimate of manned spacecraft [1-4]. The latest data in this field were summarized by Webb [5]. However, a special study had not been made of the effect of weightlessness on processes of heat exchange between the human body and artificial atmosphere of spacecraft. It is known fact that there is no thermal displacement of heated air in weightlessness (natural convection), on which heat removal in earth's gravity largely depends (about 50% of heat removal). We previously [6] determined that it is possible to experimentally test the effect of weightlessness on changes in heat loss by homothermal systems using the sensor of an electrodynamic psychrometer. The sensor of this automatic instrument reacts to a set of microclimate conditions with homothermal organisms, and makes it possible to qualitatively assess the cooling effect of a given microclimate, as well as to determine the involvement of convection and radiation in forming the dry psychrometric measurement [7].

The objective of the joint Czech-Soviet "heat transfer 1" experiment, conducted aboard the Cosmos-936 biosatellite, was to test the feasibility of direct measurement of the effect of weightlessness on heat loss by a homothermal body and influence on heat loss of forced convection at air velocities of 0-3 ms^{-1}, i.e., to obtain base data of the greatest hygienic significance.

Methods

The experiment was conducted using an automatic electrodynamic psychrometer with a calibrating device (code EDK-UT). The line diagram of the instrument is illustrated in Figure 1. The sensor of the psychrometer, which has a shiny surface of duralumin *1*, is secured on the axis of a duralumin cylinder, wind tunnel *2*. There is a fan *3* opposite the psychrometer sensory (at a distance of 10 cm).

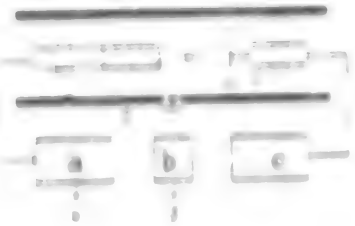

Figure 1. Line diagram of KDK-U7 instrument
a) unit for power and measurement of force delivered to sensor
b) unit for measurement of tunnel temperature
c) fan control
1) sensor
2) wind tunnel
3) fan
4) channel No 1 output (power measurement)
5) channel No 2 output (temp.)

The instrument operated on Cosmos-936 in the automatic mode, the stereotype of which is divided into 7 positions. When turned on in the first position, the psychrometer heats up to the initial state, then switches successively to the other 6 positions for readings to be taken when air velocity within the cylinder constitutes 0, 0.7, 1.2, 2.0, 3.0 and 0 ms^{-1}. There was a total of 18 measurement cycles during the flight. The power delivered to the sensor and temperature on the surface of the wind tunnel were recorded during each reading by means of the onboard tape recorder.

Since it was not possible to produce heat conditions in the synchronous ground-based experiment analogous to those aboard the biosatellite, we took control measurements using the returned flight and spare instruments in the laboratory at temperatures of the wind tunnel surface corresponding to those found during the flight. The error factor of reproduction constituted ±0.5°C. The magnitude of heat loss was determined experimentally by placing the instrument in a vacuum chamber at a residual pressure of $5 \cdot 10^{-3}$ mm Hg. An ionization anemometer was used to measure air velocity on the ground. The atmosphere in Cosmos-936 was characterized by the following parameters: barometric pressure 770÷810 mm Hg (102-108 kPa), Ta +19÷23°C, pO_2 126-210 mm Hg (16.8-27.6 kPa), pCO_2 2-8 mm Hg (0.266-1.066 kPa) and relative air humidity 40-80%. The differences between the biosatellite's artificial atmosphere and that of the ground did not have a significant effect on heat loss. The area of the sensor surface, from which heat is emitted to the environment constitutes 40 cm^2 (precision of ±1%). In order to obtain a general coefficient of heat transfer (h_ℓ) in SI system units, we used the following equation:

$$h_\ell = \frac{250\ H_h}{T_{ps} - T_{wt}}$$

where H_h is heating power, T_{ps} is psychrometer temperature (in our case, 37°C) and T_{wt} is the temperature of the wind tunnel surface which was initially in equilibrium with ambient air. The value of the coefficient of heat loss by convection (h_c) was obtained by subtracting the coefficient of heat transfer by radiation (h_r) from the overall heat loss coefficient (h_ℓ).

Results and Discussion

Figure 2 illustrates a record of one cycle of measurements of the cooling effect of the environment in weightlessness aboard Cosmos-936. In the first operating position of the instrument, the sensor heats up to 37°C, then maximum power is turned on. Then, after a brief switching to 9 position, the instrument goes into the operating mode. For technical reasons, the time in second position was

curtailed, so that it appears on the graph in the form of a recess. The measurement in still air is more graphically evident on the last, 7th step (9th-14th min of measurement). The middle of the tracing consists of four positions with forced movement of air at 0.7, 1.2, 2.0 and 3.0 m/s. As can be seen, equilibrium between sensor heat production and heat loss occurs much faster with forced convection than in still air. The dash line on the graph shows changes in wind tunnel temperature, which gradually rose (by about 0.7°C) after turning the instrument on, then stabilized when the fan was in operation. A new rise of tunnel temperature (by about 1.5°C) was observed after the fan was turned off, between the 9th and 14th min of measuring sensor heat loss in still air. This change in temperature of the walls of the wind tunnel reflects the process of accumulation of heat within the tunnel walls as a result of diminished heat loss by convection after turning the fan off.

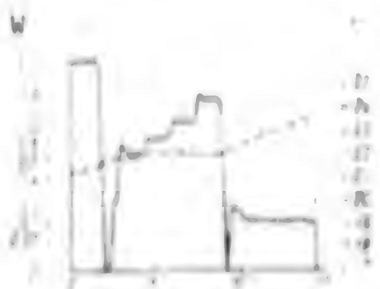

Figure 2.
Tracing of one measurement cycle aboard Cosmos-936.

X-axis, time (min); y-axis, measured power (W) on the left, temperature (°C) of wind tunnel surface on the right.

Explanation is given in the text.

The mean value of the coefficient of heat loss by radiation with the instrument we used was determined in vacuum of $5 \cdot 10^{-3}$ mm Hg (0.6 Pa). The measured radiation, as determined on the basis of 5 readings, constituted:

$$h_r = 1.150 \pm 0.057 \ W/m^2K$$

The table lists the results of 18 measurements taken aboard Cosmos-936 and 5 control readings taken under analogous conditions on the ground.

The table also lists the power fed to the sensor (M_h), integral coefficient of heat loss ([illegible]) and coefficient of heat loss by convection ([illegible]). The table shows that, according to the theoretical assumptions, maximum decrease in heat loss occurs in weightlessness in still air. By eliminating natural mixing of air (convection), overall heat loss by the psychrometer diminishes by about 47% of the value measured in earth's gravity field. The effect of weightlessness on lowering the cooling effect of the environment diminishes very rapidly under the influence of forced convection. At an air velocity of 0.7 m/s, heat emission of the psychrometer sensor constitutes 88% of the value measured on the ground, and with velocities of 2 and 3 m/s, the difference between heat loss in weightlessness and on the ground becomes statistically unreliable.

It was established that with a temperature gradient of 15°C and coefficient of emission $\varepsilon = 0.18$, radiation makes up a significant part of overall heat loss only in still air (58%). With natural convection, the share of radiation drops to 27% and with forced ventilation it becomes insignificant.

The results obtained from the "heat transfer 1" experiment confirm the hypothesis that there is a substantial decline in weightlessness of heat loss from a heated

body in a still air environment. The absence of natural convection makes it possible to measure heat conduction of air (λ) in a relatively thick layer. In our experiment, heat conduction of air (calculated without taking into consideration the cylindrical shape of the heated body) constituted $\lambda = 0.0368$ W/m °K. This is only 1.36 times greater than the well-known constant for air, and it virtually coincides with the measurements of Barton and Edholm [8].

Heat transfer parameters aboard the Cosmos-936 biosatellite

Parameter	Air velocity, m/s				
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tunnel surface temperature, °C	22.5±0.4 (22.5±0.4)	21.4±0.3 (21.9±0.6)	21.8±0.3 (21.3±0.8)	21.9±0.3 (21.5±0.6)	21.8±0.3 (21.3±0.7)
Integral heat loss coefficient, W/m^2 K	2.07±0.17 (1.41±0.2)	10.6±0.3 (13.1±0.3)	14.3±0.3 (16.3±0.4)	17.4±0.2 (17.8±0.4)	22.6±0.2 (24.2±[illegible])
Heat loss by convection, W/m^2	1.92±0.17 (3.20±0.21)	9.83±0.27 (11.3±0.3)	13.2±0.3 (14.2±0.4)	16.2±0.2 (16.7±0.4)	21.5±0.2 (22.1±0.3)
Psychrometer heating rate, W/m^2	29.7±0.1 (44.5±1.5)	147.0±2.4 (159.3±8.2)	216.6±3.4 (240.5±11.6)	262.6±4.6 (277.5±14.6)	344.0±7.6 ([illegible]±20.8)

Note: Parameters measured in a mockup of the biosatellite are given in parentheses.

Figure 3.
Heat loss by EDK-UT sensor as a function of air velocity on earth (1) and in weightlessness (2)

The fact that, as we established, there is virtually a linear relationship between air velocity and heat loss is of practical significance. It is only with a velocity of at least 2 m/s that a drastic increase in heat loss occurs, apparently due to appearance of turbulent flow (Figure 3). Heat loss by convection (h_c) can be calculated using the following empirical formulas:

a) for conditions on earth, with air velocity of less than 2 m/s,
   $h_{\alpha} = 9.44 \cdot V^{\frac{1}{2}} + 3.26$, and with velocity in excess of 2 m/s
   $h_{\beta} = 16.0 \cdot V^{\frac{1}{2}} - 5.92$;
b) in weightlessness, with velocity of less than 2 m/s,
   $h_{\alpha} = 10.68 \cdot V^{\frac{1}{2}} + 0.92$, and with velocity in excess of 2 m/s
   $h_{\beta} = 17.0 \cdot V^{\frac{1}{2}} - 7.8$.

Thus it was established that the influence of weightlessness on heat loss by a heated body is more manifest in still air or forced ventilation of up to 1 m/s. At greater velocities of forced air movement, the influence of weightlessness is canceled out. At the same time, expressly this range of velocities of artificial convection (0 to 1 m/s) is the most significant from the standpoint of hygiene.

The experimentally demonstrated function of air velocity as related to heat loss of the DK-UT sensor makes it possible to use an analogous instrument for taking measurements and, in the future, to also regulate air flow in spacecraft cabins.

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METHODS

UDC: 59.082.2

A DEVICE FOR STUDYING THE TURNING REFLEX IN SMALL LABORATORY ANIMALS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 76-78

[Article by G. S. Ayzikov, A. S. Markin and I. Yu. Sarkisov, submitted 12 Apr 79]

[Text] It is important to study animals' turning [turning over] reactions in order to investigate the mechanisms of effects of weightlessness on vestibular and motor analyzer function. This was demonstrated in studies [1-5] pursued on cats during brief weightlessness and in the aftereffect period using the classical procedure of R. Magnus [6]. This procedure turned out to be unsuitable for studying the turning reaction of rats. The fact of the matter is that the speed of the reaction, a marked grasping reflex and tail movements are considerably in advance of the motor reaction of the experimenter. The use of a soft "harness" was also unsuccessful, since rats suspended in such a device belly up turn around in the "harness" even before they start to fall.

The device we developed makes it possible to immobilize the animal reliably and for a long time in any position (including belly up), and to rapidly release it for a free fall from any initial position, with a nontraumatic landing.

Design of the device: The device consists of a container 1, stand [holder] 2, guided braking device 3, flexible rod 4, connecting line 5 and safety net 6 (Figure 1).

The stand consists of a vertical strut on a tripod. The guiding attachment for placement of the container with the animal is secured to the top part of the stand. The guides are connected to a revolving unit that permits immobilization and rotation of the container about the horizontal axis. A fine-mesh safety net is attached to the bottom of the stand for the animals to drop into. There too, a console comes out, to which the flexible rod is attached, that is connected to the removable part of the container, as well as two capron straps that converge at the top of the stand and serve as the guiding-braking device. There is a ring that slides down these straps, that is connected by a short line to the removable shell. During the fall, the latter is moved to the side and braked. The stand has a ruler to calculate the kinetograms. The stand is 180-200 cm high

Figure 2 illustrates the container with immobilized animal. The container consists of a removable shell 1, clamp 2 to secure the flexible rod, clamp 3 to secure the connecting line, stop mechanism lever 4, stop pin 5 and guides 6. The container

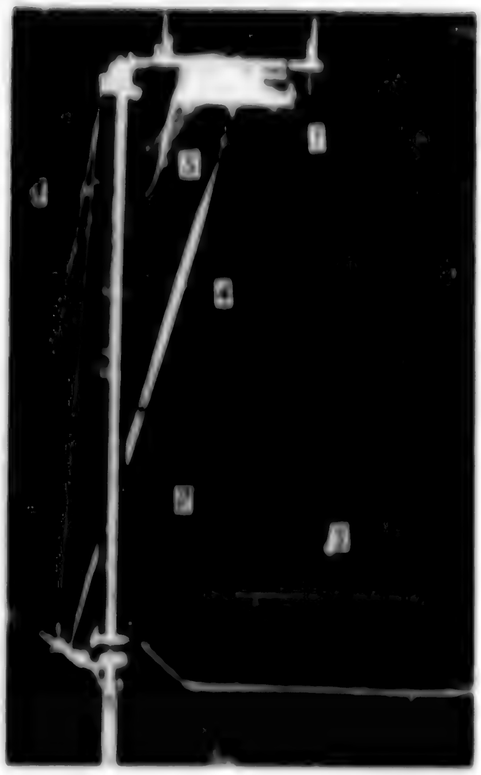

Figure 1.
[illegible] for testing turning reactions of laboratory animals. Explanation for [illegible] figures 2 and 3 is given in the text

Figure 3.
Film frame showing start of animal's free fall

Figure 2. Container with animal

is executed in the form of a platform on 4 supports with parallel slots, into which the removable semicylindrical plexiglas sheath, which presses the animal to the platform, is inserted and secured by means of the stop mechanism. The top part of the inner surface of the removable housing is lined with porolon for "soft compression" of the animal and to increase friction between touching surfaces. The ends of the removable sheath are covered with planes protruding from the platform, one of which revolves about the axis, opening the entrance to the tunnel formed by the plexiglas half-cylinder.

Operation of device: A rat is placed in the container that is removed from the stand. The removable sheath of the container is dropped into the slots of the platform to a certain depth that is sufficient to press the animal to the platform, and it is immobilized with the stop mechanism. The container with the animal is placed in the desired position on the stand (for example, with the animal's back down). The flexible rod and connecting line, linked with the guiding-braking device, are secured to the clamps of the removable container housing. The experimenter disconnects the stop mechanism at the required time. Through the action of the flexible rod, the removable sheath is catapulted and turned in an inferolateral direction from the trajectory of the animal's fall, then braked by the guiding-braking device. The rat makes a free fall from the belly up position at a height of 1-1.5 m on the safety net. We see on the film frame (Figure 3) that the removable part of the container does not hinder the rat's free fall, since it is catapulted before the animal makes any movement.

Studies of turning reactions of intact and delabyrinthectomied rats demonstrated the efficacy and reliability of operation of this device. A total of 2-3 min is required to test an animal, after which the unit is ready for operation again. The device is light (4-5 kg), it can be easily disassembled into parts and stowed in a portable case. It is simple to service and is suitable for work in both the laboratory and under field conditions. It can be used as well to test the turning reaction of other laboratory animals (for example, guinea pigs).

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BRIEF REPORTS

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EFFECT OF IONIZED AIR ENVIRONMENT ON HUMAN HORMONAL SYSTEMS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 78-81

[Article by R. A. Tigranyan, V. F. Savina, N. A. Davydova and N. F. Kalita, submitted 22 Feb 79]

[Text] There is practical importance to evaluation of the body's hormonal systems during prolonged exposure to an ionized air environment. In our opinion, it is desirable to conduct studies of this problem with evaluation of the vegeto-humoral-hormonal complex [1], which implements the system of nonspecific adaptation, the mechanisms of which are closely related to the state of the adrenosympathetic (AS), hypophysioadrenocortical and other regulatory systems of the body [1, 2].

Methods

Four men ranging in age from 25 to 35 years participated in this study; they spent 16 days in a pressure chamber 24 m^3 in size. The O_2 concentration was about 21±2%, relative humidity was 50-70% and equivalent effective air temperature was 22±2°C.

There were 4 sessions of air ionization, ionization lasting a total of 8 days. ^{14}C β-emitters served as the source of ionization, and they provided a concentration of light ions of about 35,200 per cc positive and 22,400/cc negative. The coefficient of unipolarity constituted 1.58. There were the following periods without additional air ionization: 89 h from the start of the test to the first ionization session; 31 h between the first and second sessions, 36 h between the second and third, and 36 between the third and fourth. The first session lasted 24 h, the second and third 60 h each and the fourth 48 h. The subjects were on a combined work and rest schedule. They exercised daily for the equivalent of 400 kcal in 1 h.

We analyzed venous blood and 24-h urine specimens 13 and 7 days before the study (background), on the 2d, 7th, 9th, 13th and 16th days in the pressure chamber, on the 2d and 7th days of the aftereffect period when they were on an unrestricted regimen.

AS system activity was evaluated on the basis of concentration of epinephrine (E), norepinephrine (NE) in blood plasma and excretion of E, NE, dopamine (DA) and dopa (D) in urine. We used the fluorometric method [3]. A quantitative evaluation was made of the state of the AS system, for which purpose we calculated some parameters of relative activity of different elements of catecholamine (CA) metabolism [4]. We assessed functional activity of the hypophysioadrenocortical system (HAC)

according to levels of adrenocorticotropic hormone (ACTH) and cortisol (F) content of blood, and excretion of total 17-hydroxycorticosteroids (17-HCS) and 17-ketosteroids (17-KS) in urine. The functional state of the hypophysis-thyroid system was assessed according to levels of thyrotropic hormone (TTH), thyroxin (T_4), triiodothyronine (T_3) in blood serum. Assays of blood ACTH, F, TTH, T_3, T_4, insulin and somatotropic hormone (STH) were made by the radioimmune method using sets of Amersham Co. reagents, CEA-IRE-Sorin and Byk-Mallinckrodt; 17-HCS in urine were assayed by the method of Silber and Porter [5], and 17-KS by the method of N. A. Kiskhova [6].

The obtained results were processed by the method of variation statistics using the criterion of Fisher and Student [7].

Results and Discussion

In the background period, the levels of hormones studied in blood and urine were in the physiologically normal range (Tables 1 and 2).

The beginning of the test (2d day) was associated with elevation of levels of ACTH, F, insulin, E, NE in blood and excretion in urine of E, NE, DA and 17-KS, as compared to background levels, with concurrent decrease in concentration of TTH, T_3 and T_4 in blood. It must be noted that, during this period, we observed an increase in E/NE ratio by 2 and 1.8 times in blood and urine, respectively, as compared to background level. All this was indicative of increased activity of the hormonal element of the AS system and increased functional activity of the hypophysio-adrenocortical system, and it indicated the presence of emotional stress, apparently related to the start of the test. Analogous results had been obtained by a number of other authors [5, 8, 9].

The next stage was characterized by an increase in ACTH, F, insulin and E in blood, E, DA, 17-KS in urine, the maximum elevation of levels being observed chiefly on the 13th day. Analogous changes, but in the opposite direction, were noted in NE, TTH, T_3 and T_4 of blood and NE in urine. The E/NE ratio was considerably increased on the 13th and 16th days, constituting 240 and 254%, respectively, of the background level. Relative activity of DA synthesis (DA/D) was also increased, while NE/D ratio constituted only 57.3% of the base level. Excretion of 17-HCS in urine and STH content of blood did not change throughout the testing period.

At the readaptation stage, hormone levels in blood and urine did not differ from base values, and only TTH, T_3 and T_4 levels rose.

Thus, long-term ionization was associated with a change in functional activity of the hormonal element of the AS system, hypophysioadrenocortical and hypophysio-thyroid systems (as indicated by elevation of E, ACTH, F levels in blood and increased excretion of E, DA and 17-KS in urine, as well as the decrease in TTH, T_3 and T_4 content of blood on the 13th day, which coincided with the end of the 6th cycle of ionization). The observed activation of hormonal systems was apparently instrumental in development of defense and adaptive reactions of the body to ionization. The changes in the opposite direction, which we demonstrated in the hypophysio-adrenocortical and thyroid systems, were due to the close correlation between the adrenal cortex and thyroid, which are part of the complex functional neuroendocrine system that provides for hormonal homeostasis of the body.

Table 1. Parameters of activity of adrenosympathetic system

Parameter	Period, day								
	background		chamber					aftereffect	
	[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E in blood, ng/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NE in blood, ng/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E/NE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E in urine, µg/day	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NE " " "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DA " " "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
D " " "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E/NE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NE/DA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DA/D	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

For this and Table 2: *P<0.05; **P<0.02; ***P<0.01. The "+" sign refers to P<0.001

Table 2. Hormone content of blood and urine

Parameter	Period, day								
	background		chamber					aftereffect	
	[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ACTH, pg/ml	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cortisol, µg%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17-OCS, mg/day	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17-KS, mg/day	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Insulin, µU/ml	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STH, ng/ml	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TTH, ng/ml	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T_3, ng%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T_4, µg%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Several authors previously reported opposite correlations between functional activity of the adrenal cortex and thyroid. It must be noted that total 17-HCS excretion did not change with the increased blood ACTH and F content. This is an indication not only of activation of the hypophysioadrenocortical system, but changes in correlation between free and conjugated forms of 17-HCS, reflecting changes in secretion and catabolism of steroids [12].

The increased blood F content against the background of unchanged STH hormone could, apparently, have aided in increasing the insulin concentration due to possible change in carbohydrate metabolism. It is also possible that the increase in circulating insulin was due to changes in secretion of glucagon, which can stimulate secretion thereof [13].

Along with the demonstrated changes in the hypophysioadrenocortical system, the question of diminished activity of the mediator element of the AS system in the presence of ionization is rather interesting. As a result of clinical examination, changes were found in hemodynamic parameters, which consisted of diminished minute volume of the heart, reduced heart rate (by 10-15/min) and arterial pressure drop to 100/70 mm Hg. We cannot link the correlated changes in clinical signs and activity of the mediator element of the AS system with the fact that the subjects were somewhat restricted in motor activity, since the cycle of their exercises stimulated this system daily [14-16]. Evidently, we can attribute the findings to the inhibitory effect of aeroions on activity of the mediator element of the AS system and, in particular, activity of the enzyme, dopamine-β-hydroxylase, which synthesizes NE from DA. The observed increase in mediator element of the AS system during the readaptation period (increased excretion of NE and DA in urine) was probably of a compensatory and adaptive nature when the subjects returned to their normal habitat.

Thus, the subjects' stay in a pressure chamber with an ionized air environment elicited activation of the hormonal element of the AS system, increase in functional activity of the hypophysis-adrenocortical system and stimulation of β-cells of the islets of Langerhans in the pancreas, and at the same time it had an inhibitory effect on the mediator element of the AS and hypophysis-thyroid systems.

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STUDY OF MOUSE MORTALITY AFTER EXPOSURE TO HELIUM IONS WITH ADMINISTRATION OF TILORONE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 81-82

[Article by B. S. Fedorenko, N. Ya. Talash and Yu. D. Parfenov, submitted 3 May 79]

[Text] Our objective was to make a comparative study of mortality rate of mice after exposure to helium ions and γ-rays under ordinary conditions and following preliminary administration of tilorone.* Tilorone is an inductor of interferon, which has some effect on development of radiation lesions [1, 2]. The product also has a mild radioprotective action [3].

Methods

We used 294 mice $(CBA \times C_{57}BL_6)F_1$ mice of both sexes at the age of 4 months. The animals were exposed to helium ions in doses of 500, 600 and 800 rad, with energy of 1.8 GeV/nucleon, and in a dose of 700 rad with energy of 4.6 GeV/nucleon. The dose rate constituted 1.4 and 0.4 rad/s, with ±10 homogeneity of the beam and linear energy transfer (LET) of 8.3 and 8.3 MeV/g·cm². A separate group of mice was exposed to ^{60}Co γ-rays at a dose rate of 5.5 rad/s. Several animals were given a solution of tilorone intragastrically in a dosage of 200 mg/kg body weight 18 h prior to irradiation. The synchrophasotron of the Unified Institute of Nuclear Research in Dubno was used to deliver the helium ions; γ-rays were delivered from an RKh-γ-30 unit. We kept a record of 30-day mortality.

Results and Discussion

As shown by the results of our studies (Table 1), preadministration of tilorone did not reliably lower the postradiation death rate after delivery of helium ions in doses of 600, 700 and 800 rad. At the same time, administration of tilorone 18 h before irradiation shortend the animals' life span (Table 2). On this basis, it can be concluded that preliminary administration of tilorone enhances the radiation lesion from helium ions. We observed greater effectiveness of helium ions, as compared to γ-rays.

$LD_{50/30}$ for mice exposed to helium ions constituted 593±14 rad; it was 597±24 rad for animals given tilorone and then exposed to helium ions and 326±38 rad for

*2,7-di(2-diethylaminoethyoxy)fluoren-9-one dihydrochloride.

those exposed to γ-rays. Thus, it was established that administration of tilorone does not affect the value of $LD_{50/30}$ after exposure to helium ions.

Table 1.
30-Day mouse mortality after exposure to helium ions and γ-rays

Experim. conditions	[illegible]	[illegible]	Mortality, %
Helium ions	500	16	12.5±8.3
	600	16	31.3±11.6
	700	30	66.7±8.3
	800	18	100
Tilorone & helium ions	600	16	87.5±12.1
	700	33	100
	800	18	100
γ-Rays	500	15	6.7±6.4
	600	15	6.7±6.4
	700	30	23.3±7.7
	800	18	44.6±11.7
Tilorone	—	10	0
Control	—	59	1.7±1.6

Table 2.
Mean survival time of mice after exposure to helium ions and γ-rays

Experim. conditions	[illegible]	Arithmet. mean survival time, days	Effective survival time, (ET_{50}), days
Helium ions	600	15.0±0.8	19.2±3.5
	700	10.1±0.8	8.6±0.5
	800	5.9±0.7	5.0±0.9
Tilorone &helium	600	13.0±2.9	38.2±24.0
	700	5.6±0.8	4.5±0.5
	800	3.7±0.3	2.4±0.4
γ-Rays	700	21.9±4.1	—
	800	11.5±1.4	16.4±5.9

The coefficients of relative biological effectiveness (RBE) of helium ions, calculated in relation to $LD_{50/30}$ of γ-rays constituted 1.4, which corresponds to RBE of lower energy helium ions, obtained with the criterion of mouse breast cancer cell survival [4] and parameters of rat embryo development [5].

The results of this study indicate that irradiation with helium ions with energy of 1.8 and 4.6 GeV/nucleon is biologically more effective than ^{60}Co γ-radiation (evaluated according to animal mortality).

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SEASONAL CHANGES IN LEUKOCYTE COUNT AND PHAGOCYTIC ACTIVITY OF LEUKOCYTES IN INDIVIDUALS WORKING IN A CLOSED ENVIRONMENT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 82-84

[Article by V. S. Novikov and A. M. Timofeyev, submitted 7 Dec 79]

[Text] There is extensive discussion in the literature of immunobiological processes as related to man's spending different periods of time in a closed environment [1-4]. The adaptive immunological capabilities of people who constantly work in airtight [pressurized, sealed-off] areas have been less studied [5]. There are virtually no data concerning the seasonal changes in functional state of leukocytes of specialists who work for long periods of time in a closed environment with elevated ambient temperature and noise.

Methods

A survey was made in the temperate climate zone of 43 operators ranging in age from 19 to 22 years, who worked in sealed-off rooms where ambient temperature ranged from 24 to 42°C and ambient ["atmospheric"] noise ranged from 87 to 108 dB. The subjects spent 8 h daily under these conditions. The control group (30 people) consisted of subjects in the same occupation, of the same age and with the same work tenure, but who worked under normal hygienic conditions. This study was conducted with due consideration of season: in October, January, April and July. We determine the absolute leukocyte count, as well as relative loss and absorption capacity of phagocytes, intensity of phagocyte absorption and effectiveness of the phagocytic reaction [6, 7]. We used a culture of strain 209P staphylococcus as the microbial object of absorption.

Results and Discussion

We demonstrated an increase in leukocyte count in people working in a closed environment, referable to the neutrophils and monocytes in the wintertime, and a reliable decline in the spring and summer ($P<0.05$; see Table). Similar seasonal changes were observed in the control group, and this is not inconsistent with data in the literature [8, 9]. As a rule, there was a lower leukocyte count, due to reduction in number of neutrophils and monocytes, in the experimental group, and this could lead to reduction of protective immune properties of blood [10, 11]. The eosinophil content was higher in the experimental group at all tested times, while

lymphocyte content was lower than in the control. At the same time, the changes demonstrated in leukogram parameters of specialists in the experimental group did not usually exceed the range of physiological fluctuations [12].

Seasonal changes in functional activity of leukocytes (M±m)

Time of study	Group	Leukocyte count, $10^9/\ell$	Relative phagocyte loss in 30 min	Absorpt. capacity of phagocytes	Intensity of phagocyte absorption	Degree of phagocyte reaction
Fall (Oct)	Control(30)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Main(43)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Winter (Jan)	Control(19)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Main(29)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Spring (Apr)	Control(22)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Main(29)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Summer (Jul)	Control(17)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Main(20)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*Differences ($P<0.05$), as compared to the control.
**Differences, as compared to the autumn period in the corresponding group.

Studies of the functional state of leukocytes revealed that leukocytolysis was 21-35% higher in the main group, throughout the study period, than in the control group, while leukocyte absorptive capacity was 22-36% lower. It must be stressed that these findings are nonspecific, and they are observed, in particular, among specialists working in "hot shops" [13]. The seasonal changes in parameters of functional activity of leukocytes were characterized by a decline of resistance, absorptive and digestive leukocyte functions in the spring and summer. These changes were more marked in the main [experimental] group of specialists (see Table).

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PERCEPTION OF INSTRUMENT DATA AS RELATED TO FLYING EXPERIENCE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 pp 84-86

[Article by V. V. Kniga, submitted 15 Dec 79]

[Text] Pilot perception and processing of instrument data depend on many factors. Experience in flight work is quite important in this respect.

Our objective here was to determine the link between evaluation of quality of perception and processing of instrument data under laboratory conditions and the pilots' experience in instrument flying.

The method of presenting photographic reproductions of instrument panels is one of the means of studying the quality of perception and processing of data under laboratory conditions. This method was first used by B. M. Pikovskiy in 1953 [1]. The "photomodel" method was used by G. L. Komendantov et al. to assess fatigue in on-duty pilots [2]. Concurrently, studies were pursued of the possibility of training flight personnel with the use of photomodels. M. B. Zabutyy, who used the photomodel method to simulate the discrete form of air sickness in pilots, demonstrated that the quality of instrument reading diminishes significantly, even prior to development of vegetative reactions [3]. Subsequently, various modifications of the photomodel method were proposed, and they were used for purposes of expert evaluations. A method was developed involving the use of a real mock-up of an instrument panel [4]. Methods were also developed that made use of tachistoscopes, in which one could display images of instruments with the needles in different positions, etc.

N. A. Razsolov and O. P. Yakovlev [4] evaluated professional fitness for flying with simulation of motion sickness on the basis of the results of reading aviation instruments (color slides of the An-24 aircraft instrument panel). The method of grading perception in points was used [5].

The advantage of testing the quality of perception and processing of instrument data by the photomodel method is that it does not require the use of expensive, complicated equipment, and it makes possible a quantitative evaluation of instrument reading error and time, and to take into consideration a shortage of time.

In our study of instrument data perception and processing under laboratory conditions, we tried to take into consideration the degree of nervous and mental

stress in the pilots. We determined the most informative parameters of stress referable to the main physiological functions, that can be evaluated by an aviation physician. These parameters of the pilots were recorded while they performed a task under laboratory conditions that reproduced one of the elements of flying work, the process of instrument data perception and processing. On the basis of these studies, a method was developed for quantitative evaluation of the quality of perception and processing of instrument information by means of an integral rating, which takes into consideration the degree of tension [stress] of the cardiovascular and respiratory systems in the course of the study.

Methods

In our studies, we used the modification of O. P. Yakovlev [5] of the photomodel method. During the test, we recorded the parameters of the pilots' cardiovascular and respiratory systems. On the basis of the studies, we proposed an integral evaluation of quality of perception and processing of instrument data under laboratory conditions.

We prepared a total of 47 color slides with pictures of an aircraft instrument panel for use in our studies. They were conducted in the course of outpatient certification of pilots by an aviation medical commission. Each slide was shown for 4 s. The interval between slides was the same throughout the study period, and it constituted 30 s. Thus, we exhibited 720 slides to 60 pilots. During the study we recorded the EKG, heart rate (HR) and minute volume of respiration (MV). We used the SAN method to assess the condition of the pilots and measured arterial pressure (AP) before and after the study. The pilots had to remember the readings of flight and navigation instruments, determine the position of the aircraft in space and stage of flight. Their answers were graded on a 5-point scale: correct perception of all instrument readings, determination of aircraft position in space and stage of flight was given a grade of 5; with incorrect perception of one of the instruments, the grade was dropped by 0.5 point, and with incorrect determination of the aircraft's position and stage of flight by 1 point.

The integral rating was determined by the following formula:

$$I = M + \frac{0.1\ HR_b + MV_b}{0.1\ HR_m + MV_m}$$

where I is the integral rating, M is the grade given to the pilot's answers on a 5-point scale, 0.1 is the coefficient that takes into consideration the correlation between effect of HR and MV on integral rating, and also serves to make calculations more convenient (determined empirically), the subscript "b" refers to background value and "m" to the value obtained during the test.

Parameter M takes into consideration the results of pilot performance with regard to data perception and processing under laboratory conditions, and parameters HR and MV consider the reactions of the cardiovascular and respiratory systems during this performance. In view of the fact that, in our studies, a high degree of motivation for the test was gained in the course of certification of flight personnel by the aviation medical commission, the ratio of background values to HR and MV in the laboratory tests serves as an indicator of degree of nervous-mental tension of pilots during the test. The lower this ratio, the greater the tension associated with pilot performance in perceiving and processing instrument

information under laboratory conditions and the lower the integral rating. Conversely, the greater the value of the right part of the equation, the less tension of physiological functions was associated with performance of this work.

The study was conducted in two stages; at the first stage, we examined the quality of perception and processing of instrument data, and physiological parameters of the cardiovascular and respiratory systems of pilots with different levels of ex- work experience when performing tasks under laboratory conditions that simulated these processes, by means of the method of reading photomodels of an instrument panel. At the second stage, we examined the changes in integral rating of perception and processing of instrument information under laboratory conditions as a function of flying experience.

Results and Discussion

The average grade was 4.4 (ranging from 4.1 to 4.6, depending on the difficulty of the assigned tasks) for perception and processing of instrument data by class I pilots and 4.3 (4.0-4.6) for class II pilots. The difference in grades between the two classes was insignificant and unreliable.

In class III pilots, the quality of perception and processing of instrument data was graded at 3.9, and the grade was in the range of 3.72-4.13, depending on the difficulty of the task. The difference between class III and class I pilot ratings was significant ($P<0.05$).

Integral evaluation of perception and processing of instrument data by pilots differing in flying experience

Pilot class	Mean integral rating and error factor as a function of requested task										Mean rating
	1	2	3	4	5	6	7	8	9	10	
I	5.33 ± 0.12**	5.27 ± 0.11**	5.26 ± 0.12**	5.08 ± 0.13**	5.17 ± 0.1**	5.31 ± 0.12**	5.35 ± 0.13*	5.29 ± 0.11**	5.33 ± 0.13**	5.28 ± 0.14**	5.27 ± 0.12**
II	5.28 ± 0.13*	5.22 ± 0.14*	5.22 ± 0.13**	4.98 ± 0.15*	5.12 ± 0.14*	5.21 ± 0.11**	5.23 ± 0.15*	5.22 ± 0.11*	5.25 ± 0.12*	5.16 ± 0.13*	5.19 ± 0.13*
III	4.78 ± 0.14	4.7 ± 0.15	4.73 ± 0.13	4.47 ± 0.12	4.66 ± 0.11	4.64 ± 0.11	4.82 ± 0.16	4.72 ± 0.15	4.80 ± 0.13	4.69 ± 0.14	4.7 ± 0.13

*$P<0.05$ **$P<0.01$

The difference between the grades of class III and class II pilots was less marked, but also reliable ($P<0.05$) [sic].

Our results revealed that there is a correlation between the quality of perception and processing of information and experience in flight work.

With regard to the EKG recorded during the period of performing under laboratory conditions tasks involving instrument data perception and processing, the following results were obtained. The RR interval diminished by a mean of 0.11 s in the course of the study in class I and II pilots and by 0.19 s in class III. Accordingly, HR increased by a mean of 7.8/min in class I, 10.1 in class II and 21.7 in class III pilots. The difference between class I and III pilots in HR increment was reliable ($P<0.05$). During the test, signs of sinus arrhythmia (if they were present before the test) disappeared. PQ, QRS and Q-T intervals did not change appreciably during the test. The P wave increased by an average from 1.19 to 1.38 mm in all subjects; the T wave diminished from 3.83 to 3.47 mm ($P<0.05$).

There was insignificant change in arterial pressure before and after the test. The well-being of the pilots, assessed by the SAN method, constituted 5.65 before the study and dropped to 5.32 after, which is indicative of a positive reaction to the test.

Respiration rate ranged from 10 to 17/min, depending on the nature of the experiment.

MV increased in all subjects. In class III pilots it rose from 6.7 to 8.9 l ($P<0.05$).

The changes in cardiovascular and respiratory systems obtained as a result of this study can be used as the most informative indicators of nervous and psychological tension in flight personnel.

The second phase of the study involved making an integral rating of instrument data perception and processing by pilots differing in experience. The formula included the HR and MV as the most informative parameters for evaluation of nervous and mental stress while solving problems of perception and processing of instrument data under laboratory conditions.

The Table lists the integral ratings of pilots differing in flying experience.

The integral rating constituted a mean of 5.27 (5.08 to 5.35) for class I pilots, and 5.19 (4.98-5.28) in class II. The difference between class II and I ratings is insignificant. This indicates that, considering physiological system tension, perception and processing of instrument data were about the same in class I and II pilots under laboratory conditions.

The integral rating for class III pilots averaged 4.7 (from 4.47 to 4.82). As compared to classes I and II pilots, it was considerably lower in class III ($P<0.05$ and $P<0.01$). This indicates that more tension of physiological systems is associated with perception and processing of instrument information by class III pilots, and these operations are of poorer quality than in class I and II pilots.

Thus, the integral rating reflects objectively the state of processes of perceiving and processing instrument data under laboratory conditions and it is related to the pilot's experience.

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ABSTRACTS OF ARTICLES FILED WITH THE ALL-UNION SCIENTIFIC RESEARCH INSTITUTE OF MEDICAL AND MEDICOTECHNICAL INFORMATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 6, 1980 p 96

[Abstracts]

UDC: 614.37:678.7

[Text] "Study of the Effect of Steady Magnetic Field on Gas Emission From Polymer Construction Materials," by V. D. Yablochkin.

A study was made of the effect of a stationary magnetic field (SMF) of up to 620 Oe, which is used to protect the crews of spacecraft from radioactive radiation, on gassing from 10 samples of polymers used in construction. It was shown that SMF has no appreciable effect on gassing of linear polymers, whereas exposure of mesh polymers lowers emission of volatile substances by 10-50%. The probable mechanism of action of SMF on polymers is discussed.

UDC: 612.745.1.014.477-064

"Means of Increasing Muscular Activity in Weightlessness by the Method of 'Load-Free' Muscle Tension," by A. V. Kovalik

Determination was made of the effect of deliberate [volitional] "load-free" [idle?] muscle tension (DLMT) on performance of simulated operator work. It was established that performance of motor actions under these conditions is associated with 3-5-fold increase in amplitude of muscle biopotentials (recorded from 8 muscles). Performance time was shortened by 12.4 s ($P < 0.01$), and differences in number of errors were unreliable. In order to demonstrate the effect of DLMT on functional changes in the systems of the body, movements were selected that can be readily reproduced and involve the main muscle groups: flexion and extension of the elbow, knee and ankle joints, raising and lowering the arms. The movements were performed with one and both limbs, first by the usual method then with DLMT at 50% of maximum exertion and maximum 5 and-fold intensification (2-s cycle). Pulse and respiration rate, arterial pressure, minute volume (MV) and electrical activity (EA) of muscles were recorded. In addition, skin temperature over working muscles was measured for 2 min. Analysis of the results revealed that performance of exercises in the customary way did not elicit appreciable

changes in the parameters recorded (with the exception of muscle BA). When performing exercises with maximum DLMT these parameters increased appreciably, particularly the pulse (by a mean of 17.1/min) and MV (by 10.4 ℓ). On the basis of these studies, exercises were developed for use while performing sedentary work under any conditions.

1. Lift feet of the floor, tensing muscles, moving the feet in different directions.

2. Press soles to the chair legs and tense muscles.

3. Straighten legs and tense leg muscles. If conditions do not permit stretching legs, grasp chair legs with the toes and tense muscles.

4. Tensing shoulder girdle muscles, perform arm movements in different directions.

5. Tensing back muscles, perform bends.

6. Make movements with the abdomen: forward--inspiration, backward--expiration.

7. Tense gluteal and pelvic fundus muscles.

8. Make head movements tensing neck muscles.

9. Bend and turn the trunk in different directions tensing trunk muscles.

10. Tense all body muscles (this exercise can be performed without movement also).

Each movement was performed for 10 s with 50% of maximum exertion. Analysis of the results revealed that pulse increased by 16.8/min (124.2%) when performing the exercises once (1 min 40 s), MV increased by 8.4 ℓ (158.3%) and there was insignificant change in other parameters. Performance of the set of exercises 2 and 3 times in a row resulted in virtually no further changes in recorded parameters. In view of the fact that it is difficult to monitor the EMG in a work situation, the other group of subjects performed in accordance with the following instructions: "... perform exercises with application of force equaling half the maximum exertion." In these subjects, muscular activity varied significantly, but on the average it held at 30-40% of maximum exertion and was associated with the appropriate moderate reaction of the body. Thus, it was demonstrated that one can increase muscular activity by the DLMT method at any time and with the body in any position, with and without movements, activating any muscles, without distraction from work operations or impairment thereof. Of course, in each specific case, the mode of exercise (time, repetition, degree of muscle tension, etc.) will depend on the individual distinctions of working conditions, and it is selected in accordance with flights differing in duration. In the course of the exercises, each person will be able to determine the best regimen for himself, and well-being will serve as a criterion for determining the duration and intensity of exercise.

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